Col. F.P. Lyford index in No 6

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OF THE

Marine Biological Laboratory

WOODS HOLE, MASS.

VOL. XXXIX JULY, 1920 NO. 1

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Editorial Staff

E. G. Conklin—*Princeton University.*

George T. Moore—*The Missouri Botanic Garden.*

T. H. Morgan—*Columbia University.*

W. M. Wheeler—*Harvard University.*

E. B. Wilson—*Columbia University.*

Managing Editor

Frank R. Lillie—*The University of Chicago.*

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JULY TO DECEMBER, 1920

PRESS OF
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BIOLOGICAL BULLETIN

THE MARINE BIOLOGICAL LABORATORY

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THIRTY-SECOND YEAR

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I. TRUSTEES

EX OFFICIO

FRANK R. LILLIE, *Director*, The University of Chicago.
GILMAN A. DREW, *Assistant Director*, Marine Biological Laboratory.
D. BLAKELY HOAR, *Treasurer*, 161 Devonshire Street, Boston, Mass.
GARY N. CALKINS, *Clerk of the Corporation*, Columbia University.

TO SERVE UNTIL 1923

H. C. BUMPUS, Brown University.
R. A. HARPER, Columbia University.
W. A. LOCY, Northwestern University.
JACQUES LOEB, The Rockefeller Institute for Medical Research.
GEORGE T. MOORE, Missouri Botanical Garden, St. Louis.
L. L. NUNN, Telluride, Colo.
W. J. V. OSTERHOUT, Harvard University.
W. M. WHEELER, Bussey Institution, Harvard University.

TO SERVE UNTIL 1922

CORNELIA M. CLAPP, Mount Holyoke College.
E. G. CONKLIN, Princeton University.

Ross G. Harrison, Yale University.
Camillus G. Kidder, 27 William Street, New York City.
M. M. Metcalf, Oberlin, Ohio.
William Patten, Dartmouth College.
Jacob Reighard, University of Michigan.
W. B. Scott, Princeton University.

TO SERVE UNTIL 1921

S. F. Clarke, Williamstown, Mass.
Charles A. Coolidge, Ames Building, Boston, Mass.
C. R. Crane, Woods Hole, Mass., *President of the Corporation.*
Alfred G. Mayor, Carnegie Institution.
C. E. McClung, University of Pennsylvania.
T. H. Morgan, Columbia University.
Erwin F. Smith, United States Department of Agriculture.
E. B. Wilson, Columbia University.

TO SERVE UNTIL 1920

H. H. Donaldson, Wistar Institute of Anatomy and Biology.
M. J. Greenman, Wistar Institute of Anatomy and Biology.
C. W. Hargitt, Syracuse University.
H. S. Jennings, Johns Hopkins University.
George Lefevre, University of Missouri, *Secretary of the Board.*
A. P. Mathews, The University of Chicago.
G. H. Parker, Harvard University.
Henry B. Ward, University of Illinois.

II. ACT OF INCORPORATION

No. 3170.

COMMONWEALTH OF MASSACHUSETTS

Be It Known, That whereas Alpheus Hyatt, William Sanford Stevens, William T. Sedgwick, Edward G. Gardiner, Susan Minns, Charles Sedgwick Minot, Samuel Wells, William G. Farlow, Anna D. Phillips and B. H. Van Vleck have associated themselves with the intention of forming a Corporation under the name of the Marine Biological Laboratory, for the purpose of establishing and maintaining a laboratory or station for scientific study and investigation, and a school for instruction in biology and natural history, and have complied with the provisions of the statutes of this Commonwealth in

such case made and provided, as appears from the certificate of the President, Treasurer, and Trustees of said Corporation, duly approved by the Commissioner of Corporations, and recorded in this office;

Now, therefore, I, HENRY B. PIERCE, Secretary of the Commonwealth of Massachusetts, *do hereby certify* that said A. Hyatt, W. S. Stevens, W. T. Sedgwick, E. G. Gardiner, S. Minns, C. S. Minot, S. Wells, W. G. Farlow, A. D. Phillips, and B. H. Van Vleck, their associates and successors, are legally organized and established as, and are hereby made, an existing Corporation, under the name of the MARINE BIOLOGICAL LABORATORY, with the powers, rights, and privileges, and subject to the limitations, duties, and restrictions, which by law appertain thereto.

Witness my official signature hereunto subscribed, and the seal of the Commonwealth of Massachusetts hereunto affixed, this twentieth day of March, in the year of our LORD ONE THOUSAND, EIGHT HUNDRED and EIGHTY-EIGHT. HENRY B. PIERCE,

[SEAL.] *Secretary of the Commonwealth.*

III. BY-LAWS OF THE CORPORATION OF THE MARINE BIOLOGICAL LABORATORY

I. The annual meeting of the members shall be held on the second Tuesday in August, at the Laboratory, in Woods Hole, Mass., at 12 o'clock noon, in each year, and at such meeting the members shall choose by ballot a Treasurer and a Clerk, who shall be, *ex officio*, members of the Board of Trustees, and Trustees as hereinafter provided. At the annual meeting to be held in 1897, not more than twenty-four Trustees shall be chosen, who shall be divided into four classes, to serve one, two, three, and four years, respectively, and thereafter not more than eight Trustees shall be chosen annually for the term of four years. These officers shall hold their respective offices until others are chosen and qualified in their stead. The Director and Assistant Director, who shall be chosen by the Trustees, shall also be Trustees, *ex officio*.

II. Special meetings of the members may be called by the Trustees, to be held in Boston or in Woods Hole at such time and place as may be designated.

III. The Clerk shall give notice of meetings of the members by publication in some daily newspaper published in Boston at least fifteen days before such meeting, and in case of a special meeting the notice shall state the purpose for which it is called.

IV. Twenty-five members shall constitute a quorum at any meeting.

V. The Trustees shall have the control and management of the affairs of the Corporation; they shall present a report of its condition at every annual meeting; they shall elect one of their number President and may choose such other officers and agents as they may think best; they may fix the compensation and define the duties of all the officers and agents; and may remove them, or any of them, except those chosen by the members, at any time; they may fill vacancies occurring in any manner in their own number or in any of the offices. They shall from time to time elect members to the Corporation upon such terms and conditions as they may think best.

VI. Meetings of the Trustees shall be called by the President, or by any two Trustees, and the Secretary shall give notice thereof by written or printed notice sent to each Trustee by mail, postpaid. Seven Trustees shall constitute a quorum for the transaction of business. The Board of Trustees shall have power to choose an Executive Committee from their own number, and to delegate to such Committee such of their own powers as they may deem expedient.

VII. The President shall annually appoint two Trustees, who shall constitute a committee on finance, to examine from time to time the books and accounts of the Treasurer, and to audit his accounts at the close of the year. No investments of the funds of the Corporation shall be made by the Treasurer except approved by the finance committee in writing.

VIII. The consent of every Trustee shall be necessary to dissolution of the Marine Biological Laboratory. In case of dissolution, the property shall be given to the Boston Society of Natural History, or some similar public institution, on such terms as may then be agreed upon.

IX. These By-Laws may be altered at any meeting of the Trustees, provided that the notice of such meeting shall state that an alteration of the By-Laws will be acted upon.

X. Any member in good standing may vote at any meeting, either in person or by proxy duly executed.

IV. THE TREASURER'S REPORT

Marine Biological Laboratory Balance Sheet, December 31, 1919

Assets

Cash in bank	$ 14,077.69	
Petty cash at Woods Hole	200.00	$ 14,277.69
Notes receivable (secured)		1,000.00
Accounts receivable		10,178.23
Inventories (not available)		
Items in suspense		131.82
Investments:		
Securities (Schedule I.)	11,768.83	
Cash (Schedule II.)	814.58	12,583.41
Stock in General Biological Supply Company, Inc.		10,000.00
Gansett property account	22,559.88	
Less mortgage	14,629.21	7,930.67
Educational plant (Schedule III.):		
Land	95,856.14	
Buildings	174,713.44	
Equipment	78,179.37	
	348,748.95	
Less reserve for depreciation	28,543.46	320,205.49
		$376,307.31

Liabilities

Accounts payable accrued (estimated)		$ 1,300.00
Notes payable issued in part payment of shares of General Biological Supply Company, Inc.	$ 4,500.00	
Less amounts paid thereon	2,000.00	2,500.00
Notes payable issued on account of purchase of investment securities	2,000.00	
Trust funds	10,583.41	12,583.41
Balancing account:		
Balance, January 1	347,558.18	
Special donations	7,500.00	
Excess of income for year (Exhibit B)	4,314.79	
New equipment transferred from expense	550.93	359,923.90
		$376,307.31

MARINE BIOLOGICAL LABORARORY, INCOME AND EXPENSE FOR YEAR ENDED DECEMBER 31, 1919

		Expense	Income	Loss	Gain
Administrative expense		$ 6,556.84		$ 6,556.84	
Bar Neck property expense		168.00		168.00	
BIOLOGICAL BULLETIN and annual dues		2,773.38	2,972.34		198.96
Carpenter department		858.14	35.05	823.09	
Chemical department		1,422.80		1,422.80	
Dexter House special expense		141.95		141.95	
Dormitory department		1,874.87	2,083.93		209.06
Instruction		5,023.36	6,395.00		1,371.64
Interest on notes payable		142.54		142.54	
Lectures, evening		90.65		90.65	
Lectures, philosophical		100.00		100.00	
Library department		2,185.50		2,185.50	
Maintenance, buildings and grounds		4,997.99		4,997.99	
Mess		21,302.46	21,462.32		159.86
New laboratory expense		3,760.02		3,760.02	
Newman cottage		50.41		50.41	
Pumping station expense		374.01		374.01	
Research department		2,045.15	4,250.00		2,204.85
Sundry expense and income		1,611.13	6,437.85		4,826.72
Supply department:					
General expense	$20,438.36				
Administration department expense	1,200.00				
Boats	6,064.04				
Fish trap	1,365.78				
Maintenance, buildings and grounds	200.00				
Pumping station	187.00				
Truck	507.23				
Rental and depreciation	2,503.80	32,466.21	36,671.08		4,204.87
Truck		507.23		507.23	
Total current expenses		88,452.64	80,307.57	21,321.03	13,175.96
Total income		80,307.57		13,175.96	
Excess of expenses		$ 8,145.07		8,145.07	
Depreciation		7,403.22			
Accounts charged off		396.92			
		15,945.21			
Contribution by Friendship Fund, Inc.	$20,000.00				
Others	260.00	20,260.00			
Balance to balancing account		4,314.79			

MARINE BIOLOGICAL LABORATORY INVESTMENTS (BOOK VALUES), DECEMBER 31, 1919

Reserve Fund

$3,000 American Telephone & Telegraph Company, 4's (represented by receipts for same as collateral)	$2,921.25	
500 Western Telephone & Telegraph Company, 5's	496.88	
6 shares American Smelting and Refining Company, Preferred (receipt on file)	732.00	
8 shares General Electric Company	948.05	
14 shares United Shoe Machinery Company, Preferred	393.75	
5 shares Massachusetts Gas Companies, Preferred	444.63	$ 5,936.56

Lucretia Crocker Fund

$300 Liberty Loan Bonds, 4¼'s	300.00	
1/5 of $1,000 American Telephone & Telegraph Company, 4's	194.75	
18 shares Vermont & Massachusetts Railway Company	2,416.50	
1 share American Telephone & Telegraph Company	125.02	
3 shares General Electric Company	364.85	
1 share West End Street Railway Company	83.00	3,484.12

Library Fund

$300 Liberty Loan Bonds, 4¼'s	300.00	
4/5 of $1,000 American Telephone & Telegraph Company, 4's	779.00	
3 shares American Telephone & Telegraph Company	375.04	
1 share American Smelting and Refining Company, Preferred (receipt on file)	122.00	
3 shares General Electric Company	362.10	
5 shares United Shoe Machinery Company, Preferred	140.63	
3 shares Massachusetts Gas Companies, Preferred	269.38	2,348.15
Total, Exhibit A		$11,768.83

January 22, 1920

MR. D. BLAKELY HOAR,
161 Devonshire Street,
Boston.

Dear Sir: We have completed our audit of the accounts of the Marine Biological Laboratory for the year ended December 31, 1919, as kept both at your office in Boston and at Woods Hole, and report thereon in the accompanying exhibits and schedules:

Exhibit A—Balance-Sheet as of December 31, 1919.

B—Income-and-Expense for the Year ended December 31, 1919.

Schedule I—Investments (Book Values).
II—Cash Receipts and Payments on Account of Investments.
III—Summary of Inventory of Land, Buildings, and Equipment.
IV—Depreciation Reserve.

We certify that, subject to the comments herewith, the balance-sheet and income-and-expense statement shown in Exhibits A and B are in accordance with the books and correct to the best of our knowledge and belief.

Very respectfully,
(*Signed*) HARVEY S. CHASE & COMPANY,
Certified Public Accountants.

V. THE DIRECTOR'S REPORT

January 1, 1920

TO THE TRUSTEES OF THE MARINE BIOLOGICAL LABORATORY:

Gentlemen: I beg to present herewith a report of the thirty-second session of the Laboratory for the year 1919: The conclusion of the war found the Laboratory with its organization intact and ready to continue its work. It was anticipated that there would probably be a rather slow recovery of ground lost during the war, and we were hardly prepared for an influx of students and investigators that carried the attendance beyond the previous high water mark. The demand for working places by investigators and students was, however, so large that it was necessary to refuse a considerable number of applications. The Laboratory has in fact outgrown its accommodations in all departments.

It is felt by most members of the Laboratory that the student attendance should not be increased, and that the tendency to overcrowding must be dealt with by yet more rigorous requirements. On the research side, the situation is more serious; it is practically impossible to accommodate all well qualified investigators who apply, and the effort to do so results in undue crowding. This situation is aggravated by the fact that the old

wooden buildings, to which the great majority of the investigators must be assigned, are increasingly ill-adapted to the changing requirements of biological research. Another large, firmly constructed, fireproof building has become a necessity.

At the time of the organization of the Division of Biology and Agriculture of the National Research Council, the needs of the Marine Biological Laboratory for additional support were presented by the Director, and a committee of the Division was appointed which investigated the situation and recommended that the National Research Council lend its aid in securing funds for the erection of a new building and for extension of the library. The report was considered by the Executive Committee of the Division and passed on with its approval and endorsement to the Executive board of the Council which functions for the whole organization. The report was then thoroughly considered and heartily approved by the Executive Board.

The support of the National Research Council is thus definitely pledged to our projects for a new building and extension of the library, but this does not relieve us of the necessity of using our own efforts for the attainment of these immediate objects. The National Research Council does not possess funds of its own for such projects, but uses its great influence to reinforce the best projects of scientific research. With such endorsement our efforts should be rewarded more rapidly than we could otherwise expect.

The tabular view of attendance (p. 20) shows a total attendance of 262 (students 128, and investigators 134) which is twenty greater than the previous largest year (1915). This number cannot be exceeded until another laboratory is built. The receipts from students and investigators were $10,545 in 1919 as compared with $8,725 in 1916, $7,850 in 1917, and $6,530 in 1918. The number of subscribing institutions was 47 in 1919; the largest previous number was 40 in 1916; in 1918 the number was 33.

During the year the business of the Supply Department was reorganized in such a way as to charge to it all items, hitherto carried on the books as general expense items, with which it was properly accountable; and as an offset it was credited with

supplies furnished students and investigators, which had previously not been accounted for. It was thought thus to place the department on a sound business basis, so that in its future development no uneasiness might be felt by its expansion. It was found necessary also during the year to raise the general price level 40 per cent., by two successive 20 per cent. increments, over pre-war figures. The items charged to the Department are the following: General expense (including salaries and supplies), administration expense, boat expense, fish trap expense, maintenance of buildings and grounds of the department, proportional share of pumping expense, truck, rental and depreciation. The credits of the Supply Department consist of sales and (for 1919) a credit of $3,000, the estimated value of material furnished students and investigators. The total income of the Supply Department on this basis for 1919 amounted to $36,671.08, and the total expense to $32,466.21. The previous largest year's business of the Department was $21,096.65 in 1916. Making due allowance for the $3,000 credit in 1919, not previously allowed, and also for the 40 per cent. increase in prices, operative only during the latter half of the year, it will be seen that a most gratifying increase in business was effected.

The development of this department requires additional laboratory space and better winter quarters for the personnel. Therefore with the approval of the Board of Trustees an additional frame building adjacent to the present quarters was begun in the fall of 1919. This building will provide for all the office and preparation work of the Department, and the old building will be used mainly for storage.

Another step in the extension of the Supply Department during the year was purchase of a controlling interest in the General Biological Supply House located in Chicago. This house was organized by Dr. M. M. Wells, formerly Assistant Professor of Zoölogy in the University of Chicago, and is managed entirely by University trained men who can be trusted to maintain high standards. It was hoped to accomplish several purposes by this venture; first, by making Chicago a distributing center for the West considerable savings in time of delivery and in shipping expense can be accomplished; in the second place, new lines of

supplies such as microscopic slides and lantern slides can be developed without enlarging the Woods Hole organization; the market for Woods Hole supplies should also be largely increased by the better attention to marketing that can be given by a strictly business organization.

During the year Dr. H. McE. Knower, who had acted for many years as librarian offered his resignation. During his term of office the library has undergone its greatest development, and owing to his efforts it has been well arranged and catalogued. The Board of Trustees in accepting Dr. Knower's resignation instructed the Secretary to express to him the appreciation which all felt of the value of his services to the Laboratory. The office of librarian was filled by the appointment of Dr. R. P. Bigelow, librarian of the Massachusetts Institute of Technology. Mrs. T. H. Montgomery, Jr. was appointed resident assistant librarian in immediate charge of the library. At the meeting of the Corporation August 12, 1919, Professor W. M. Wheeler, of the Bussey Institution, Harvard University, was elected a member of the Board of Trustees of the class of 1923 to succeed Dr. John C. Phillips

Attention is called to the very satisfactory report of the Treasurer (p. 5), and to the list of the Staff, of Investigators and Students, the Tabular View of Attendance, the Subscribing Institutions, the evening lectures, and of the Members of the Corporation which are appended as parts of the Director's report.

1. THE STAFF

1919

FRANK R. LILLIE, Director, Professor of Embryology, and Chairman of the Department of Zoölogy, The University of Chicago.
GILMAN A. DREW, Assistant Director, Marine Biological Laboratory.

ZOÖLOGY

I. INVESTIGATION

GARY N. CALKINS, Professor of Protozoölogy, Columbia University.
E. G. CONKLIN, Professor of Zoölogy, Princeton University.
GILMAN A. DREW, Assistant Director, Marine Biological Laboratory.

GEORGE LEFEVRE, Professor of Zoölogy, The University of Missouri.
FRANK R. LILLIE, Professor of Embryology, The University of Chicago.
C. E. MCCLUNG, Professor of Zoölogy, University of Pennsylvania.
T. H. MORGAN, Professor of Experimental Zoölogy, Columbia University.
E. B. WILSON, Professor of Zoölogy, Columbia University.

II. INSTRUCTION

W. C. ALLEE, Professor of Biology, Lake Forest College.
GEORGE A. BAITSELL, Instructor in Biology, Yale University.
ROBERT H. BOWEN, Graduate Student, Columbia University.
ROBERT CHAMBERS, JR., Cornell University Medical College.
ANN H. MORGAN, Professor of Zoölogy, Mount Holyoke College.
CHARLES L. PARMENTER, Research Fellow, University of Pennsylvania.
W. J. CROZIER, Assistant Professor of Zoölogy, The University of Chicago.

PROTOZOÖLOGY

GARY N. CALKINS, Professor of Protozoölogy, Columbia University.
LOUISE H. GREGORY, Assistant Professor of Zoölogy, Barnard College.

EMBRYOLOGY

I. INVESTIGATION

(*See Zoölogy*)

II. INSTRUCTION

GILMAN A. DREW, Assistant Director, Marine Biological Laboratory.
CHARLES G. ROGERS, Professor of Comparative Physiology, Oberlin College.
HUBERT B. GOODRICH, Associate Professor of Zoölogy, Wesleyan University.
ELIZABETH A. SMITH, Assistant Professor, University of Wisconsin.
B. H. GRAVE, Professor of Biology, Knox College.

PHYSIOLOGY

I. INVESTIGATION

ALBERT P. MATHEWS, Professor of Biochemistry, The University of Cincinnati.
RALPH S. LILLIE, Professor of Biology, Clark University.
HAROLD C. BRADLEY, Professor of Physiological Chemistry, University of Wisconsin.

II. INSTRUCTION

RALPH S. LILLIE, Professor of Biology, Clark University.
FRANK P. KNOWLTON, Professor of Physiology, Syracuse University.
A. R. MOORE, Professor of Physiology, Rutgers College.

PHILOSOPHICAL ASPECTS OF BIOLOGY AND ALLIED SCIENCES

LECTURES

EDWARD G. SPAULDING, Professor of Philosophy, Princeton University.

BOTANY

I. INVESTIGATION

EDWARD M. EAST, Professor of Experimental Plant Morphology, Harvard University.
ROBERT A. HARPER, Professor of Botany, Columbia University.
E. NEWTON HARVEY, Professor of Physiology, Princeton University.
WINTHROP J. V. OSTERHOUT, Professor of Botany, Harvard University.

II. INSTRUCTION

IVEY F. LEWIS, Professor of Biology, University of Virginia.
WILLIAM D. HOYT, Associate Professor of Biology, Washington and Lee University.
WM. RANDOLPH TAYLOR, Instructor in Botany, University of Pennsylvania.

LIBRARY

H. MCE. KNOWER, Professor of Anatomy, University of Cincinnati.
PRISCILLA B. MONTGOMERY, Assistant Librarian.

CHEMICAL SUPPLIES

OLIVER S. STRONG, Assistant Professor of Neurology, College of Physicians and Surgeons, New York City, Chemist.

SUPPLY DEPARTMENT

G. M. GRAY, Curator.
JOHN J. VEEDER, Captain.
E. M. LEWIS, Engineer.
A. W. LEATHERS, Collector.
A. M. HILTON, Collector.
J. MCINNIS, Collector.
F. G. GUSTAFSON, Collector in Botany.
EDNA E. WELLS, Clerk.

F. M. MACNAUGHT, Business Manager.
HERBERT A. HILTON, Superintendent of Buildings and Grounds.

2. STUDENTS AND INVESTIGATORS—1919

INDEPENDENT INVESTIGATORS—ZOÖLOGY

ACKERT, JAMES E., Professor of Zoölogy, Kansas State Agricultural College.
ADDISON, WILLIAM H. F., Professor of Normal Histology and Embryology, University of Pennsylvania.
ALLEE, WARDER C., Professor of Biology, Lake Forest College.
ALLEN, EZRA, University of Pennsylvania.
ALTENBURG, EDGAR, Instructor in Biology, Rice Institute.
BAITSELL, GEORGE A., Assistant Professor of Biology, Yale University.
BECKWITH, CORA J., Associate Professor of Zoölogy, Vassar College.
BRIDGES, CALVIN B., Research Assistant, Columbia University.
CALKINS, GARY N., Professor of Protozoölogy, Columbia University.
CHAMBERS, ROBERT, Assistant Professor of Anatomy, Cornell University Medical College.
CHARLTON, HARRY H., Acting Director of Anatomical Dept., Fordham University.
CLAPP, CORNELIA M., Emeritus Professor of Zoölogy, Mount Holyoke College.
CLARK, ELEANOR L., Columbia, Mo.
CLARK, ELIOT R., Professor of Anatomy, University of Missouri.
CONKLIN, EDWIN G., Professor of Biology, Princeton University.
COPELAND, MANTON, Professor of Biology, Bowdoin College.
CROZIER, WILLIAM J., Assistant Professor of Zoölogy, University of Chicago.
CURTIS, MAYNIE R., Associate in Cancer Research, Columbia University.
CURTIS, W. C., Professor of Zoölogy, University of Missouri.
DANCHAKOFF, VERA, Assistant Professor of Anatomy, College of Physicians and Surgeons.
DAWSON, JAMES A., Yale University.
DODDS, GIDEON S., Assistant Professor of Histology, West Virginia University.
DONALDSON, HENRY H., Professor of Neurology, Wistar Institute.
DONALDSON, JOHN C., Instructor in Anatomy, University of Cincinnati Medical School.
DREW, GILMAN A., Assistant Director, Marine Biological Laboratory, Woods Hole.
GLASER, OTTO C., Professor of Biology, Amherst College.
GLASER, RUDOLF W., Bussey Institution.
GOODRICH, HUBERT B., Associate Professor of Zoölogy, Wesleyan University.
GRAVE, BENJAMIN H., Professor of Biology, Knox College.
GRAVE, CASWELL, Professor of Zoölogy, Washington University.
GREGORY, LOUISE H., Assistant Professor of Zoölogy, Barnard College.
HEILBRUNN, LEWIS V., Brooklyn, N. Y.
HOLT, CAROLINE M., Assistant Professor of Biology, Simmons College.
HYMAN, LIBBIE H., Research Assistant, University of Chicago.
KINDRED, JAMES E., Instructor in Biology, Western Reserve University.
KNOWER, HENRY McE., Professor of Anatomy, University of Cincinnati.
LEFEVRE, GEORGE, Professor of Zoölogy, University of Missouri.
LEWIS, WARREN H., Research Associate, Carnegie Institution of Washington.
LEWIS, MRS. WARREN H., Baltimore, Md.
LILLIE, FRANK R., Chairman, Department of Zoölogy, University of Chicago.
LOEB, LEO, Professor of Comparative Pathology, Washington University.

MALONE, EDWARD F., Professor of Histology, University of Cincinnati.
MAST, SAMUEL O., Professor of Zoölogy, Johns Hopkins University.
MAVOR, JAMES W., Professor of Zoölogy, Union College.
MCCLUNG, CLARENCE E., Chairman Division of Biology and Agriculture, National Research Council.
METCALF, MAYNARD M., Oberlin College.
METZ, CHARLES W., Research Associate, Carnegie Institution, Cold Spring Harbor.
MORGAN, ANN H., Professor of Zoölogy, Mount Holyoke College.
MORGAN, THOMAS H., Professor of Experimental Zoölogy, Columbia University.
MORRILL, CHARLES V., Instructor in Anatomy, Cornell Medical College.
MULLER, HERMANN J., Instructor, Columbia University.
NABOURS, ROBERT K., Professor of Zoölogy, Kansas Agricultural College.
PARMENTER, CHARLES L., Instructor, University of Pennsylvania.
PATTEN, WILLIAM, Professor of Biology, Dartmouth College.
PINNEY, MARY E., Professor of Biology, Lake Erie College.
PLOUGH, HAROLD H., Associate Professor of Biology, Amherst College.
RICHARDS, A., Professor of Zoölogy, Wabash College.
ROGERS, CHARLES G., Professor of Comparative Physiology, Oberlin College.
SCHRADER, FRANZ, Columbia University.
SMITH, ELIZABETH A., Assistant Professor, University of Wisconsin.
SPAULDING, EDWARD G., Professor of Philosophy, Princeton University.
SPEIDEL, CARL C., Professor, St. Lawrence University.
STOCKARD, CHARLES R., Professor of Anatomy, Cornell University Medical College.
STURTEVANT, ALFRED H., Research Assistant, Columbia University.
WEINSTEIN, ALEXANDER, Investigator, Carnegie Institution.
WHEDON, ARTHUR D., Instructor in Zoölogy, University of Pennsylvania.
WHITING, PHINEAS W., Professor of Biology, Franklin and Marshall College.
WIEMAN, HARRY L., Professor of Zoölogy, University of Cincinnati.
WILSON, EDWARD B., Professor of Zoölogy, Columbia University.

BEGINNING INVESTIGATORS—ZOÖLOGY

ADAMS, A. ELIZABETH, Associate Professor of Zoölogy, Mount Holyoke College.
ANDERSON, E. G., Instructor, Cornell University.
BOWEN, ROBERT H., Graduate Student, Columbia University.
BROCKETT, DOLORES, Technical Assistant, University of Chicago.
BROWN, ALBERT M., Columbia University.
DANIELS, HELEN, Assistant, Columbia University.
GOODRICH, CLARA C., Middletown, Conn.
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LANCEFIELD, DONALD E., Assistant in Zoölogy, Carnegie Institution.
MASON, ELEANOR D., Assistant, Carnegie Institution, Cold Spring Harbor.
MATSUI, KENKICHI, Imperial College of Agriculture, Japan.
NONIDEZ, JOSE F., Research Associate, Carnegie Institution.
PATTEN, MARY W., Assistant, Yale University.
PEARCE, CHARLOTTE C., Blauvelt, N. Y.
PHILLIPS, RUTH L., Professor of Biology, Western College for Women.
REED, PHOEBE C., Assistant, Carnegie Institution.
RICHTER, MAURICE N., Student, Columbia University.

SAFIR, SHELLEY R., Teacher, Stuyvesant High School, New York City.
SHAFFER, ELMER L., Procter Fellow in Biology, Princeton University.
WALLACE, EDITH M., Research Assistant, Columbia University.
WILLIER, BENJAMIN H., University of Chicago.

INDEPENDENT INVESTIGATORS—PHYSIOLOGY

BALDWIN, FRANCIS M., Assistant Professor, Iowa State College.
BRADLEY, HAROLD C., Professor of Physiological Chemistry, University of Wisconsin.
CLOWES, G. H. A., Director and Consulting Chemist, Research Laboratory, Eli Lilly & Co.
EDWARDS, DAYTON J., Lecturer in Physiology, Cornell University Medical College.
ELLIS, FREDERICK W., Monson, Mass.
FORBES, ALEXANDER, Instructor in Physiology, Harvard Medical School.
GARREY, WALTER E., Professor of Physiology, Tulane University.
HARVEY, E. NEWTON, Professor of Physiology, Princeton University.
HECHT, SELIG, Assistant Professor, Creighton University.
HYDE, IDA H., Professor of Physiology, University of Kansas.
IRWIN, MARIAN, Radcliffe College.
JUST, E. E., Professor of Physiology, Howard University.
KNOWLTON, F. P., Professor of Physiology, Syracuse University.
LILLIE, RALPH S., Professor of Biology, Clark University.
LOEB, JACQUES, Head of Division of Experimental Biology, Rockefeller Institute.
LYON, ELIAS P., Professor of Physiology, University of Minnesota.
MATHEWS, ALBERT P., Professor of Biochemistry, University of Cincinnati.
MAXWELL, S. S., Associate Professor of Physiology, University of California.
MOORE, A. R., Professor of Physiology, Rutgers College.
PRATT, FREDERICK H., Honorary Fellow in Biology, Clark University.
REDFIELD, ALFRED C., Assistant Professor, University of Toronto.
SPAETH, REYNOLD A., Associate in Physiology, Johns Hopkins University.
WARREN, HOWARD C., Professor of Psychology, Princeton University.
WOODWARD, ALVALYN E., Instructor, Simmons College.

BEGINNING INVESTIGATORS—PHYSIOLOGY

BRAY, A. W. L., Assistant Professor of Biology, Montana University.
BRIGHT, ELIZABETH M., Research Assistant, Harvard Medical School.
CATTELL, MCKEEN, Teaching Fellow, Harvard Medical School.
FREIBERG, JOSEPH A., Medical College, University of Cincinnati.
GREISHEIMER, ESTHER M., Instructor, University of Minnesota.
KEITH, LUCILE G., Research Chemist, Eli Lilly & Co.
OBRESHKOVE, VASIL, Student, Harvard University.
OLMSTED, JAMES, Assistant in Zoölogy, Harvard University.
POND, SAMUEL E., Fellow, Clark University.
SAMPSON, MYRA M., Assistant Professor, Smith College.
STARR, ISAAC, JR., University of Pennsylvania.
STONE, AMY E., Radcliffe College.

INDEPENDENT INVESTIGATORS—BOTANY

BROOKS, SUMNER C., Research Fellow, Harvard Medical School.
FENN, WALLACE O., Harvard Medical School.

HARPER, ROBERT A., Professor of Botany, Columbia University.
HAZEN, TRACY E., Assistant Professor of Botany, Columbia University.
HOYT, WILLIAM D., Associate Professor of Biology, Washington and Lee Univ.
LEWIS, IVEY F., Professor of Biology, University of Virginia.
OSTERHOUT, WINTHROP J. V., Professor of Botany, Harvard University.

BEGINNING INVESTIGATORS—BOTANY

BROOKS, MRS. S. C., Boston, Mass.
GLUCK, MARGUERITE L., Columbia University.
HOLLAND, DOROTHY F., Summit, N. J.
TAYLOR, WILLIAM R., Instructor in Botany, University of Pennsylvania.

1919

STUDENTS

ZOÖLOGY

ADAMS, KATHRENE, Student, Radcliffe College.
ALLEN, AGNES L., Student, Mount Holyoke College.
AVINS, EMMA R., Student, Oberlin College.
BARNES, CORNELIA L., Student, Mount Holyoke College.
BECK, ELIZABETH B., Student, University of Chicago.
BELCHER, FRANCES E., Barnard College.
BENNER, ROBERT W., Heidelberg University.
BERGNER, DOROTHY, Student, Goucher College.
BILLIG, FLORENCE G., Supervisor of Nature-Study and Elementary Science, State Normal School, Emporia, Kansas.
BLANCHARD, ELNORA R., Student, Simmons College.
BUFFUM, CLARISSA G., Student, Mount Holyoke College.
CASE, MURIEL A., Hartford, Conn.
DOWDEN, FLORENCE V., Fairmont, W. Va.
ELLIS, LAWRENCE B., Student, Harvard University.
ELLIS, MILDRED, Student, Radcliffe College.
FALK, ISIDORE S., Assistant, Department of Public Health, Yale University.
FLEMING, MRS. GEORGE W., 1000 Park Ave., New York City, N. Y.
GOULD, ALICE, Student, Mount Holyoke College.
HARRIS, HARRIET E., Lake Forest College.
HAY, DOROTHY A., Student, Sophie Newcomb College.
HILL, RUTH, Brooklyn, N. Y.
HILBORN, EDITH L., Student, Knox College.
HOADLEY, LEIGH, Student, University of Michigan.
HOFFMAN, Agnes, Lake Forest College.
JOHNSON, HELEN G., Biology Teacher, Hartford High School.
KELLER, NELLE, Vassar College.
LILLIE, MARGARET H., Student, University of Chicago.
MCCLUNG, RUTH C., Student, University of Pennsylvania.
MCDONALD, HELEN E., Butler College.
MANGAM, ELIZABETH, Smith College.

MAYER, ERNA H., Vassar College.
MEKEEL, AMY G., Instructor in Zoology, Cornell University.
MILLS, RUTH L., Student, Knox College.
MUNRO, CAROL W., University of Wisconsin.
NICHOLAS, JOHN S., Yale University.
PIERCE, DOROTHY R., Student, Mount Holyoke College.
ROCK, MARIAN, Student, Sophie Newcomb College.
ROTHERMEL, JULIA E., Student, Mount Holyoke College.
SCRIBNER, AGNES E., Amherst, Mass.
SHELDON, MARGARET, Student, Oberlin College.
SMITH, CATHARINE, Smith College.
SPRINGER, MARY G., Student, Oberlin College.
ST. CLAIR, HARRIET W., Student, Vassar College.
STACEY, HELEN R., Simmons College.
STERNBERG, LILLIAN, Student, Barnard College.
SUMMERILL, VERNA B., Student, Goucher College.
TOWNSEND, ERIC B., Student, Swarthmore College.
TYLER, JOCELYN, Student, Oberlin College.
WATT, LUCY J., Western College for Women.
WATTS, MARGARET V., Student, Hunter College.
WHITE, CLARISSA D., Barnard College.
WILDER, ISABELLE M., Student, Wheaton College.
WONDERGEM, HENRY E., Student, University of Rochester.
WOODBRIDGE, HELEN, Student, Mount Holyoke College.
ZOELLER, ADELAIDE M., Student, Sophie Newcomb College.

PROTOZOÖLOGY

AGERSBORG, HELMER P. K., Instructor, Long Island College Hospital.
BELL, MARY M., Instructor, Wellesley College.
CUTRIGHT, FRANK, West Virginia Wesleyan College.
FINLEY, CHARLES W., Lincoln School of Teachers College, New York.
FISHER, MARY J., Instructor in Zoölogy, Cornell University.
MONTANUS, JOHN J., Columbia University.
NUTE, BERTHA E., Torrington, Conn.
RHODES, ROBERT C., Professor of Biology, Emory University.
SHIELDS, WALTER J., Columbia University.
SHUMWAY, WALDO, Assistant Professor of Biology, Dartmouth College.
STOCKMAN, CHARLES C., 2D, Instructor in Public Health, Yale University.
STUNKARD, H. W., Assistant Professor, University of Illinois.
WARREN, HERBERT S., College of the City of New York.
WHITING, ANNA Y., 834 Marietta Ave., Lancaster, Pa.
YOUNG, DONNELL B., North Hanover, Mass.

EMBRYOLOGY

ANDERSON, ETHEL L., Mount Holyoke College.
BALL, RUTH J., Student, University of Vermont.
BEEKLEY, CATHARINE W., 40 West 85th St., New York City.
BROWN, SUSAN W., Graduate Assistant, University of Missouri.
BROWN, LELAND A., Student, Denison University.

CLOSSON, MARY B., Student, Ursinus College.
CONKLIN, MARY, Goucher College.
DANIELS, MANNING S., Student, Denison University.
DRIVER, CHARLES S., Weyers Cave, Va.
EBELING, KARL W., Johns Hopkins University.
ELLIOTT, MARGARET, Knox College.
FOLGER, HARRY T., Assistant, Indiana University.
FREAS, ELLA M., Mount Holyoke College.
GATES, GORDON E., Foxcroft, Maine.
GILSON, ARTHUR S., JR., Dartmouth College.
GREENE, LOIS D., Student, Grinnell College.
HEIZER, HELEN S., Student, Radcliffe College.
HUNTER, ISABELLE L., Student, Simmons College.
KIMBALL, MARY A., Student Simmons College.
KREIDEL, GEORGE A., Instructor, St. Joseph's Seminary.
LANG, DOROTHY M., University of Vermont.
LAGEMANN, ANNA E., Student, Barnard College.
MORRIS, RUTH M., Wellesley College.
ROEHM, HILDA E., Wellesley College.
STEHLE, MABEL E., Instructor in Zoölogy, Clemson College.
STEVENS, KENNETH P., Wesleyan University.
STEWART, WALTER B., Student, Princeton University.
SWETT, FRANCIS H., Laboratory Assistant, Yale University.
TUERS, RUSSELL V., Instructor in Biology, New York University.
UHLEMEYER, BERTHA, Assistant in Zoölogy, Washington University.
WATERMAN, HARRIET C., Assistant, Vassar College.
WHEATLEY, MARJORIE A., Laboratory Assistant, New York State Dept. of Health.
WHITE, GERTRUDE M., Instructor, Carnegie Institute of Technology.

PHYSIOLOGY

BRUNSWICK, DAVID, Harvard Medical School.
CLINTON, ISABELLA M., Woman's Medical College of Pennsylvania.
DZUSHI, HISATAKE, Student, Amherst College.
EISENBERGER, JOHN P., Instructor in Physiology, University of Buffalo.
GUTMANN, JAMES, Columbia University.
GUTMAN, MARGARET B., Smith College.
HARRISON, BRUCE M., Assistant Professor of Zoölogy, Iowa State College.
HOSMER, HELEN R., Cleveland, Ohio.
HOWARD, FREDERICK H., Professor of Physiology, Williams College.
JAMISON, GEORGE W., Student, Franklin and Marshall College.
MACCARTHY, KATHLEEN S., Teacher, Hunter College.
MORTON, MARGARET V., Student, Bryn Mawr College.
OKEY, CATHERINE W., Instructor in Biology, Western College for Women.
SILVERBERG, WILLIAM V., Columbia University.
SPERO, STERLING D., Columbia University.
STRANG, JAMES M., Massachusetts Institute of Technology.
SYKES, GEORGE F., Professor, Oregon Agricultural College.

BOTANY

DOWELL, RUTH I., Student, Smith College.
ESTY, FRANCES F., Student, Vassar College.

GRAHAM, MARGARET A., Instructor, Hunter College.
KAAN, HELEN N., Instructor, Wheaton College.
KLEMM, RALPH A., Student, Bucknell University.
QUINNAN, BERTHA C., Teacher, Pauline Shaw School, Boston.
WEBSTER, JANET, Student, Radcliffe College.
ZIRKLE, CONWAY, Student, University of Virginia.

3. TABULAR VIEW OF ATTENDANCE

	1915	1916	1917	1918	1919
INVESTIGATORS—Total	137	129	129	93	138
Independent:					
Zoölogy	69	70	63	51	69
Physiology	20	23	23	16	24
Botany	6	7	8	5	7
Under Instruction:					
Zoölogy	36	25	24	16	22
Physiology	4	3	6	3	12
Botany	2	1	5	2	4
STUDENTS—Total	105	102	83	69	128
Zoölogy	47	50	46	41	55
Protozoölogy	—	—	—	—	15
Embryology	37	26	16	12	33
Physiology	15	14	13	10	17
Botany	6	12	8	6	8
TOTAL ATTENDANCE	242	231	212	162	266
INSTITUTIONS REPRESENTED—					
Total	79	73	77	72	88
By investigators	59	51	60	49	61
By students	42	45	36	38	62
SCHOOLS AND ACADEMIES REPRESENTED.					
By investigators	3	—	2	—	—
By students	9	3	5	—	4

4. SUBSCRIBING INSTITUTIONS—1919

AMHERST COLLEGE
BARNARD COLLEGE
BOWDOIN COLLEGE
BRYN MAWR COLLEGE
BUTLER COLLEGE

Carnegie Institution of Washington
College of Physicians and Surgeons
Columbia University
Cornell University Medical College
Creighton University
Dartmouth College
Goucher College
Harvard University
Harvard University Medical School
Hunter College (Else Seringhaus Scholarship)
Indiana University
Johns Hopkins University
Kansas State Agricultural College
Lake Forest College
Eli Lilly & Co.
Mount Holyoke College
New York University
Oberlin College
Princeton University
Radcliffe College
Rice Institute
Rockefeller Institute for Medical Research
Simmons College
Smith College
Sophie Newcomb College
University of Chicago
University of Cincinnati
University of Illinois
University of Kansas
University of Michigan
University of Missouri
University of Pennsylvania
University of Rochester
University of Vermont
University of Wisconsin
Vassar College
Wesleyan University
Western Reserve University
Wheaton College
Wistar Institute for Anatomy and Biology
Wellesley College
Yale University

SUBSCRIPTION TABLES

LUCRETIA CROCKER SCHOLARSHIP
FRIEND OF THE LABORATORY

5. EVENING LECTURES, 1919

Tuesday, July 8,
DR. ROBERT CHAMBERS. . . . . "Physical Properties of Protoplasm as Demonstrated by Microdissection."

Friday, July 11,
DR. R. A. EMERSON. . . . . "The Contribution of Genetics to Studies of Endosperm Development."

Tuesday, July 15,
DR. E. N. HARVEY. . . . . "Bioluminescence" with Demonstrations.

Friday, July 18,
DR. G. H. A. CLOWES. . . . . "Mustard and Other War Gases; their Penetration, Mode of Action and Counteraction in the Body."

Tuesday, July 22,
DR. W. T. BOVIE. . . . . "The Action of Rays on Protoplasm."

Thursday, July 24,
DR. E. S. MORSE. . . . . "The Experiences of a Collector."

Friday, July 25,
DR. C. F. W. MCCLURE. . . . . "The Analysis of Experimental Edema in the Anura."

Tuesday, July 29,
DR. FRANK M. CHAPMAN. . . . . "The Distribution of Bird Life in the Andes."

Friday, Aug. 1,
DR. L. J. HENDERSON. . . . . "The Equilibrium between Oxygen and Carbonic Acid in Blood."

Tuesday, Aug. 5,
DR. C. E. MCCLUNG. . . . . "Co-operation in Science, and the National Research Council."

Thursday, Aug. 7,
MR. W. LYMAN UNDERWOOD. . . "Hunting with Canoe and Camera in New Brunswick."

Friday, Aug. 8,
DR. SELIG HECHT....."The Nature of the Sensitivity of Animals to Light."
Monday, Aug. 11.
DR. CHRISTO A. DAKO....."Albanian Rights and Claims to Independence."
Tuesday, Aug. 12,
DR. R. A. HARPER....."Some Studies of Morphogenesis in Cœnobic Plants."
Thursday, Aug. 14,
MISS ANNA NOVAKOVA....."New Czecho Slovak State."
LIEUT. PECK....."Conditions in Central Europe."

Friday, Aug. 15..
DR. R. CONSTANTIAN....."Constantinople."

6. MEMBERS OF THE CORPORATION

LIFE MEMBERS

ALLIS, MR. E. P., JR., Palais Carnoles, Menton, France.
ANDREWS, MRS. GWENDOLEN FOULKE, Baltimore, Md.
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CAREY, MR. ARTHUR ASTOR, Fayerweather St., Boston, Mass.
CLARKE, PROF. S. F., Williamstown, Mass.
CONKLIN, PROF. EDWIN G., Princeton University, Princeton, N. J.
CRANE, MR. C. R., Woods Hole, Mass.
DAVIS, MAJOR HENRY M., Syracuse, N. Y.
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KIDDER, MR. NATHANIEL T., Milton, Mass.
KING, MR. CHAS. A.
LEE, MRS. FREDERIC S., 279 Madison Ave., New York City, N. Y.
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MARRS, MRS. LAURA NORCROSS, 9 Commonwealth Ave., Boston, Mass.
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MASON, MISS IDA M., 1 Walnut St., Boston, Mass.
MEANS, MR. JAMES HOWARD, 196 Beacon St., Boston, Mass.
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MINNS, MISS SUSAN, 14 Louisburg Square, Boston, Mass.
MINNS, MR. THOMAS, 14 Louisburg Square, Boston, Mass.
MORGAN, MR. J. PIERPONT, JR., Wall and Broad Sts., New York City, N. Y.
MORGAN, PROF. T. H., Columbia University, New York City, N. Y.
MORGAN, MRS. T. H., New York City, N. Y.
NOYES, MISS EVA J.
NUNN, MR. LUCIAN L., Telluride, Colo.
OSBORN, PROF. HENRY F., American Museum of Natural History, New York City, N. Y.
PHILLIPS, DR. JOHN C., Windy Knob, Wenham, Mass.
PHILLIPS, MRS. JOHN C., Windy Knob, Wenham, Mass.
PORTER, DR. H. C., University of Pennsylvania, Philadelphia, Pa.
PULSIFER, MR. W. H., Newton Center, Mass.
ROGERS, MISS A. P., 5 Joy St., Boston, Mass.
SEARS, DR. HENRY F., 86 Beacon St., Boston, Mass.
SHEDD, MR. E. A.
SMITH, MRS. C. C., 286 Marlboro St., Boston, Mass.
THORNDIKE, DR. EDWARD L., Teachers College, Columbia University, New York City, N. Y.
TRELEASE, PROF. WILLIAM, University of Illinois, Urbana, Ill
WARE, MISS MARY L., 41 Brimmer St., Boston, Mass.
WHITNEY, MR. HENRY M., Brookline, Mass.
WILCOX, MISS MARY A., Wellesley College, Wellesley, Mass.
WILLIAMS, MRS. ANNA P., 505 Beacon St., Boston, Mass.

WILSON, DR. E. B., Columbia University, New York City, N. Y.
WILSON, PROF. W. P., Commercial Museum, Philadelphia, Pa.

7. CORPORATION MEMBERSHIP LIST

AUGUST, 1919

ADDISON, DR. W. H. F., University of Pennsylvania Medical School, Philadelphia, Pa.
ADAMS, MISS A. E., Mount Holyoke College, South Hadley, Mass.
AGERSBORG, MR. H. P. K., Hoagland Laboratory, Long Island College Hospital, Brooklyn, N. Y.
ALLEE, DR. W. C., Lake Forest College, Lake Forest, Ill.
ALLEN, PROF. EZRA, Ursinus College, Collegeville, Pa.
ALLYN, MISS HARRIET M., Hackett Medical College, Canton, China.
ALSBERG, DR. C. S., U. S. Dept. of Agriculture, Washington, D. C.
ALTENBURG, DR. EDGAR, Rice Institute, Houston, Texas.

BAITSELL, DR. GEORGE A., Yale University, New Haven, Conn.
BAKER, MRS. L. D., 123 Chiswick Road, Boston, Mass.
BAKER, DR. E. H., American Institute of Science, Chicago, Ill.
BALDWIN, DR. F. M., Iowa State College, Ames, Iowa.
BANCROFT, PROF. F. W., Aloha Farm, Concord, Calif.
BECKWITH, MISS CORA J., Vassar College, Poughkeepsie, N. Y.
BEHRE, MISS ELINOR H., Sophie Newcomb Memorial College, New Orleans, La.
BIGELOW, PROF. M. A., Teachers College, Columbia University, New York City.
BIGELOW, PROF. R. P., Mass. Institute of Technology, Cambridge, Mass.
BINFORD, PROF. RAYMOND, Guilford College, Guilford College, N. C.
BORING, MISS ALICE M., Union Medical College, Peking, China.
BOX, MISS CORA MAY, University of Cincinnati, Cincinnati, Ohio.
BOWEN, DR. ROBERT H., Columbia University, New York City, N. Y.

BRADLEY, PROF. HAROLD C., University of Wisconsin, Madison, Wis.
BRIDGES, DR. CALVIN B., Columbia University, New York City.
BRUMFIEL, DR. DANIEL M., University of Iowa, Iowa City, Iowa.
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BYRNES, DR. ESTHER F., 193 Jefferson Ave., Brooklyn, N. Y.

CALKINS, PROF. GARY N., Columbia University, New York City.
CALVERT, PROF. PHILIP P., University of Pennsylvania, Philadelphia, Pa.
CARLSON, PROF. A. J., University of Chicago, Chicago, Ill.
CAROTHERS, MISS ELEANOR E., University of Pennsylvania, Philadelphia, Pa.
CARVER, PROF. GAIL L., West Lake, Ga.
CARY, DR. L. R., Princeton University, Princeton, N. J.
CASTEEL, DR. D. B., University of Texas, Austin, Texas.
CATTELL, PROF. J. MCKEEN, Garrison-on-Hudson, N. Y.
CATTELL, MR. MCKEEN, Harvard Medical School, Boston, Mass.
CHAMBERS, DR. ROBERT, JR., Cornell University Medical College, New York City, N. Y.
CHARLTON, MR. HARRY H., Osborn Zoölogical Laboratory, Yale University, New Haven, Conn.
CHESTER, PROF. WEBSTER, Colby College, Waterville, Maine.
CHIDESTER, PROF. F. E., West Virginia University, Morgantown, W. Va.
CHILD, PROF. C. M., University of Chicago, Chicago, Ill.
CLAPP, PROF. CORNELIA M., Mount Holyoke College, South Hadley, Mass.
CLARK, PROF. E. R., University of Missouri, Columbia, Mo.
CLOWES, PROF. G. H. A., Eli Lilly Co., Indianapolis, Ind.
COE, PROF. W. R., Yale University, New Haven, Conn.
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CRANE, MRS. C. R., Woods Hole, Mass.
CURTIS, PROF. W. C., University of Missouri, Columbia, Mo.
CURTIS, DR. MAYNIE R., Crocker Laboratory, Columbia University, New York City.

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SEXUAL DIMORPHISM IN NEMERTEANS.

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It has been generally assumed by zoölogists that the sexes of the nemerteans are indistinguishable, with the exception of possible size and color differences, without an examination of the gonads. While this is generally true certain facts have been recently brought to light which show, as will be explained below, that in at least one genus the sexes are truly dimorphic. The male in this case not only bears the gonads in an entirely different part of the body than does the female, but is also distinguished by the possession of a pair of large lateral appendages which are apparently used as copulatory organs. The only other instance of an external appendage in nemerteans is the caudal cirrus in *Micrura* and related genera, but this is without relation to sex.

Many cases are known in which both size and color differences distinguish the sexes when mature. Thus it has long been known that in the common *Cerebratulus lacteus* Ver. the males in the breeding season (Coe, '95) are suffused with bright red in the anterior portions of the body and deep red in the intestinal region where the spermaries are located, while the females are much darker, duller red or brownish red, with a grayish tinge except in the anterior portions of the body. This differentiation in color is apparent some two or three months before the sexual products are ready to be discharged, in April, although in the summer and autumn months both sexes are nearly alike, with pinkish white bodies and yellowish or brownish intestinal diverticula. Many other species show somewhat similar differences in color when sexually mature, or in the breeding season of those which live for several years. It seems not improbable that the sexes in every species if carefully observed would likewise be recognizable by color modifications when their sexual products are ripe.

Little evidence is available as to the size factor in relation to

sex, but in general the exceptionally large individuals are females.

The third external sexual character, in which a real dimorphism of the sexes occurs, has been found only in a single family living in the deep sea in various parts of the world. And although both males and females of one of these forms have been known for many years the sexes have hitherto been placed in different genera. The form to which reference is made was described by Verrill nearly thirty years ago (1892) as the type of a new family, Nectonemertidæ, the males being placed in the genus *Nectonemertes*. The species was named by him *N. mirabilis*. The most remarkable feature of this new genus was the presence of a pair of lateral appendages, or tentacles, on the sides of the body just back of the head.

A. Sexual Dimorphism in Nectonemertes.

Verrill correctly noted the fact that in *N. mirabilis* the smaller and immature individuals had very short, or rudimentary, tentacles while in the largest specimen these organs attained a length much greater than the diameter of the body. The four specimens which Verrill had for study were collected by the United States Fish Commission Steamer Albatross in the North Atlantic Ocean in the region of the Sargasso Sea, between 37 and 41 degrees north latitude and between 66 and 73 degrees west longitude. The depth of water at the collecting stations varied from 600 to 1,700 fathoms. These specimens and one other from the same locality have recently been fully studied by the writer, and all prove to be males.

The worms of this species have a remarkably fish-like appearance (Figs. 1, 2), with much flattened bodies, with horizontal fins along the posterior half of the body, and a broad terminal tail fin. They are obviously adapted to a pelagic existence, and although there is no positive evidence as to the exact depth at which this particular species lives, yet several other species of the genus are known to live at intermediate depths in the deep oceans, and other forms of a somewhat similar organization have been taken in a closing net at a depth of several hundred fathoms. The epithelium covering the body in all these forms is mostly dislodged during capture, and in one or two species mentioned

below the change in pressure between their natural habitat and the surface has caused the rupture of the body walls and the extrusion of certain of the internal organs. The evidence all points to a pelagic life at great depths, that is, from several hundred feet to hundreds of fathoms. That is to say, they are truly bathypelagic organisms.

In the same collection and from the same locality were two specimens which Verrill ('92) described as belonging to another genus and species, *Hyalonemertes atlantica*, with characteristics very similar to those of *Nectomertes*, but which lacked any trace of tentacles. By a curious error, evidently made in transcribing his notes, the ovaries of these females were incorrectly described by Verrill as the gonads of *Nectonemertes*. But for this confusion it is possible that Verrill would have himself recognized the sexual dimorphism of this form.

Since Verrill's original description of *Nectonemertes* several other species of the genus have been described from as many different localities. One species, *N. pelagica* Cravens and Heath ('06), occurs off the coast of California. Another, *N. japonica* Foshay ('12), lives in Japanese waters. Three others, *N. grimaldii* Joubin ('04) from west of the Azores, *N. chavesi* Joubin ('06) from south of the Azores, *N. lobata* Joubin ('06) from near the Azores, were each described from the superficial study of a single specimen. As the specific distinctions rest largely on the peculiarities of the tentacles, Joubin's three supposed species may eventually prove to represent merely growth stages of but a single species.

The tentacles of *N. chavesi* were represented merely by blunt papillæ or short tubercles (Fig. 11, *t*) in the only specimen studied by Joubin. The photograph shows indication of minute cephalic spermaries (Fig. 11, *sp*), although Joubin did not recognize them as such. Both these characters indicate an immature male individual. In *N. grimaldii*, on the other hand, both tentacles and cephalic spermaries are well developed (Fig. 9), indicative of a mature male. Joubin correctly describes the external appearance of the spermaries, but suspected that they might be organs of a glandular or sensory nature. In the single specimen of *N. lobata* available for study by Joubin, one of the

tentacles was prolonged into a slender filament. This presumably represents merely a relaxed condition of the tentacle, for Verrill ('92) describes one or two of his specimens of *N. mirabilis* as having similar filamentous terminal portions, while in others the tentacles were contracted into relatively shorter and thicker appendages, as shown in Fig. 1.

Bürger ('09) studied and described anatomically one specimen of *Nectonemertes* from off the coast of Jumba, French Congo, which he identified as *N. mirabilis*. Finally Brinkmann ('16) has described *N. minima* from three males and one female, also collected off the west coast of Africa.

In *N. minima* the tentacles are similar to those of *N. mirabilis*, as are also those of *N. pelagica* (Fig. 19). All of these descriptions, however, were made from dead or preserved specimens. The appearance of the living animal in one of these forms, *N. mirabilis*, is shown in Fig. 18. In life the tentacles are much longer and more slender than they appear in the preserved specimen. A comparison of Figs. 18 and 19, although representing different species, will indicate the change in form which takes place upon the death of the animal.

Thus far about twenty-four specimens of the seven species enumerated above have been described as having tentacles, and all were males. Verrill, Joubin, and Bürger recognized the close structural similarity between *Nectonemertes* and *Hyalonemertes*, but Brinkmann ('12) was the first to suggest that they might represent dimorphic forms of a single species. As the name given to the male, *Nectonemertes*, has priority over that of the female, *Hyalonemertes* in Verrill's work ('92), Brinkmann correctly refers his species to the former genus.

It has been mentioned that more male individuals than females of the various species of this genus have been studied. For example, Cravens and Heath found only males in their five specimens of *N. pelagica*, while Foshay was sent six specimens of *N. japonica*, which were likewise all males. Three reasons for this suggest themselves. First, the tentacles of the male are presumably adapted for clasping and holding the female. As a result of their clinging instinct the worms hold fast to any small foreign object such as a fishing line or bait or the mesh of

a net which may be lowered to their habitat. The males are thereby drawn to the surface and collected. Second, the very conspicuous appendages of the males would direct attention to them as unusual objects and they would be carefully preserved by the inexperienced collector—and some of the specimens are known to have been obtained in this way—while the closer resemblance of the females to other common species of nemerteans would seem to give them a lesser importance. And, finally, it seems very possible from such meager descriptions as Joubin ('06) gives of six supposedly new species of *Planktonemertes* that one or more of them may actually be females of species of *Nectonemertes*, for they come from the same general region of the North Atlantic Ocean; that is, from stations west of the Azores only a few degrees apart. With these and perhaps other considerations in mind it is not surprising that more males than females of the various species are known.

Gonads.—The two sexes in *Nectonemertes* are distinguished not only by the tentacles characteristic of the males but also by the position and appearance of the gonads. The spermaries of the male (Fig. 1) are limited to the head region, while the ovaries of the female are situated in their primitive positions between the intestinal diverticula along the sides of the body (Fig. 2). The general appearance of the two sexes thereby becomes so strikingly different that their original separation into different genera is hardly surprising.

Tentacles.—Microscopic study of the tentacles of *Nectonemertes* shows that they represent slender outgrowths of the body walls; the integumentary, basement, and muscular layers being the same in both. The muscular layers, however, assume a direction at right angles to those of the body, and are of far greater thickness. The central part of the appendage is filled with an extension of the body parenchyma, with blood lacunæ of large size, and two very large nerves which originate from several branches of the lateral nerve cord at points near the base of the tentacle.

The structure of the tentacles indicates clearly that these organs are capable of a high degree of muscular contraction. The filamentous character of their terminal portions when well developed suggests that they are not simply locomotor organs,

but that they are specially adapted for grasping. The highly developed horizontal and caudal fins show that the animals are free swimming. When it is remembered further that the tentacles reach their full size only at the time of sexual maturity, the conclusion seems reasonable that they are then used for grasping the female and clinging to her during the act of insemination, as Brinkmann ('12) has suggested. Associated with these organs are spermaries with highly muscular walls (Fig. 8) opening by sperm ducts leading to the ventral surface of the head directly anterior to the tentacles (Figs. 1, 8). The number of such spermaries is limited to from twenty to thirty. The female also differs from most littoral nemerteans, but agrees with those of other bathypelagic species in having relatively few pairs of ovaries along the sides of the body (Fig. 2). And each ovary produces but one or two eggs of relatively enormous size as compared with those of most littoral species.

The reduction in the number of spermatozoa to a small fraction of the number found in a worm of a littoral species of similar size, and a corresponding reduction in the number of ova produced by the female, has evidently necessitated a conservation of the genital products by adaptations for securing the fertilization of the maximum proportion of the eggs produced.

Hence the advantage of pairing instincts and organs for accomplishing this result in place of the more primitive and wasteful processes which obtain in the littoral forms. These latter, it will be remembered, in many cases discharge an enormous number of spermatozoa and minute eggs into the water about them, with relatively small chances of any particular egg producing an embryo. In some of the smaller forms, on the other hand (as *Amphiporus*), there is a kind of pairing in which the two sexually mature individuals of opposite sex place their bodies side by side and the genital products of both are discharged together in a mass of mucus secreted by the integument of the two worms. The littoral forms moreover live in a comparatively limited environment and thus have a great advantage in this respect over these bathypelagic species, the habitat of which may extend over hundreds of miles of ocean, with a vertical range of several hundred fathoms. Hence, the advantage of

organs by which the sexes when mature may be held together until insemination occurs. For it may be assumed that fertilization of the eggs takes place within the body of the female, as in several well-known littoral and terrestrial species. The early formation of the oviducts indicates that this is probable, although we have as yet no direct evidence that it actually occurs. Moreover, it may be not unreasonable to suspect the possibility of embryonic development within the mother's body, which in the known viviparous forms is often associated with eggs of unusual size, as in *Geonemertes*, for example (Coe, '04).

The position of the sperm ducts on the ventral surface of the head just anterior to the tentacles, where they could be most effectually pressed against the open oviducts of the female, is a further indication that internal fertilization takes place. And finally, the highly muscular walls of the spermaries (Fig. 8), which are found only in bathypelagic species, doubtless serve for the forcible ejection of the spermatozoa through the slender sperm ducts which open at the summit of small extensible papillæ. The weakness of the musculature of the body walls is thus compensated for by the special musculature of the spermary. In *Bathynectes murrayi* Brinkmann finds similar muscular spermaries connected with slender sperm ducts which extend as penes far beyond the surface of the body (Figs. 15, 16, *pe*), as described below. Such a condition indicates that the sperm ducts may be actually inserted into the open oviducts of the female. Then by the contraction of the musculature of the spermary some of the spermatozoa contained in the latter would be forced into direct contact with the one or two large ova which each ovary contains. The smaller genital papillæ of *Nectonemertes* may function in a similar manner.

In littoral and terrestrial species where fertilization takes place within the body of the female the two worms, after coming in contact, secrete a great abundance of mucus which surrounds the two animals as a sheath and prevents the escape of the spermatozoa after they have been discharged by the male. These bathypelagic species, on the other hand, are but poorly supplied with mucus secreting glands and hence appear to require the actual introduction of the spermatozoa into the oviducts in order that fertilization may be assured.

B. Sexual Differentiation in Other Bathypelagic Nemerteans.

The distinction between sexual differentiation and sexual dimorphism should closely be borne in mind. As commonly used the former term has reference to those characteristics which distinguish the sexes in a form in which both sexes are easily recognized as belonging to the same species, while the latter implies morphological features so profound that the two sexes might appear to belong to different species or even larger groups. Among the nemerteans known at the present time only *Nectonemertes*, and possibly *Balænanemertes*, belong to the latter category.

It may be worth while to consider in this connection a few of the many cases of sexual differentiation which lead toward the true sexual dimorphism described above for *Nectonemertes*. In many species of nemerteans there can be no question as to sexual differentiation, for all individuals are hermaphroditic and to some extent protandric, as in the fresh-water *Stichostemma* and the terrestrial *Geonemertes* (Coe, '04). Here the young and small individuals function as males. A period of growth commonly follows the discharge of most of their spermatozoa, when they assume the characteristics of the female. In some cases both spermatozoa and ova develop at the same time. Some of these forms are viviparous, but there are also several cases of viviparity known among littoral species which are neither hermaphroditic nor protandric.

The primitive condition of the reproductive organs in the nemerteans, as is well known, is that of separate sexes, in both of which the gonads occupy similar positions along each side of the body throughout almost its entire length back of the head. The gonads are usually in pairs, alternating regularly with the intestinal lobes, or diverticula. The number of such gonads may be many thousands in a large worm, and each ovary as well as each spermary produces a large number of gametes. It is estimated that a large female Cerebratulus, which may reach a length of two meters or more, produces upwards of one hundred millions of eggs in one season. These are all discharged within the space of a few days. And in some littoral species no

larger than *Nectonemertes* the number of eggs produced is at least a hundred times greater than in the latter.

In all the bathypelagic forms the gonads of both sexes are reduced in number and size to but a small fraction of those of littoral species. A comparison of the forms hitherto described with respect to these structures will show a graded series leading to the extreme condition found in *Paradinonemertes* in which the male is provided with but two pairs of spermaries (Fig. 17 *sp*).

In all the bathypelagic forms moreover the spermaries are limited to the anterior regions of the body, and indeed in most species are far removed from their primitive position to the region of the head. In a few forms they are even limited to the area in front of the brain, where they are crowded into a dense cluster on each side of the head, with their sperm ducts opening near the lateral borders of the mouth.

In the female the ovaries remain in all species in their primitive interdiverticular positions, but as the number of intestinal diverticula becomes reduced the ovaries suffer a corresponding reduction. The extreme limit in the species known at present appears to be four or five pairs, which number occurs typically in *Pelagonemertes rollestoni*.

1. *Planktonemertes*.—In *Planktonemertes* occurs one of the first steps in the process of reduction. Strangely enough, however, of the several species of this genus thus far described only the females are known with the exception of the single specimen of *P. alberti*, in which Joubin (1906) clearly shows the two groups of spermaries behind the brain. This investigator did not, however, suspect their true nature. Fortunately an exceptionally well preserved specimen of *P. agassizii* has recently come into my hands which proves to be a sexually mature male. This was collected by the U. S. Fish Commission Steamer Albatross from near the equator in longitude 81° West; that is, off the coast of Ecuador. A study of this specimen reveals nine rounded spermaries on one side and eleven on the other, situated immediately back of the brain, medially to the lateral nerves, and laterally to the pylorus (Fig. 3, *sp*). These spermaries presumably represent the anterior interdiverticular gonads

of littoral species, although they lie far anterior to the intestine proper. Yet in this and related forms the intestinal diverticula extend far forward, even in front of the brain in many cases. It is evident that in their embryonic development these diverticula actually grow anteriorly from their primitive lateral positions, and it is quite conceivable that they carry with them the rudiments of the gonads and that only those gonads which are thus carried forward develop into spermaries. Serious objections to this hypothesis are, first, that the number of spermaries bears no relation to the number of cephalic diverticula present in the adult, and, second, even with this hypothesis a certain amount of independent migration would be necessary to give the spermaries their definite localization.

The number of intestinal diverticula in this species is commonly between thirty and fifty and the ovaries retain their primitive positions between them (Fig. 4). One of the females available for study, although of large size, had the ovaries in a very early stage of development. In this case these organs alternated regularly with the intestinal diverticula except toward the posterior end of the body. But in the specimens with mature ovaries the number was much less than that of the diverticula, ranging from about fifteen to twenty pairs (Fig. 4). Evidently some of the original ovaries have failed to develop or have been absorbed by the body tissues.

This process if carried still farther would result in a condition similar to that which Bürger ('06) found in a related species, *P. woodworthi*, in which there are only seven or eight pairs of ovaries. Bürger also found in a specimen which he erroneously identifies as *P. agassizii* "numerous" very young ovaries which alternate regularly with the diverticula in the middle portions of the body, although he does not state the precise number. Brinkmann ('16) studied a single female of *P. vanhöffeni* which had just discharged the eggs from fourteen pairs of ovaries.

The conditions in the females of all these species are thus quite in harmony with the account given above for *P. agassizii*, but only in the latter species has the male been discovered.

2. *Balænanemertes*.—Bürger ('09) describes from a single specimen a new genus which in his opinion forms a connecting link

between the nemerteans with and those without tentacular appendages. This species, *Balænanemertes chuni*, was taken in the Indian Ocean, in a region where the depth of water was 2,500 meters. This specimen, although a sexually mature male with cephalic gonads, was provided with a pair of short sickle-shaped lateral processes, or papillæ (Fig. 10, *t*) closely resembling the rudimentary tentacles in the young individuals of *Nectonemertes mirabilis*. It is by no means certain, however, that these processes might not have developed into longer tentacles if the individual had lived until the spermatozoa were quite ready to be discharged. They would doubtless have been much more conspicuous in life than they appear in the preserved specimen, for the tentacles of Nectonemertes are such highly distensible organs that they suffer enormous contraction upon preservation, as is indicated in figures 18 and 19.

There are five pairs of spermaries in this species. These are situated immediately behind the brain. Each gonad opens by a short sperm duct which leads to the summit of a blunt or rounded papilla (Fig. 10, *sp*) on the lateral border of the head. Female is still unknown.

3. *Bathynectes*.—In *Bathynectes murrayi* Brinkmann ('12) finds a remarkable modification of the reproductive organs in the male. In this bathypelagic nemertean from the North Atlantic the spermaries are provided with muscular walls as in *Nectonemertes*, and the sperm ducts, instead of ending in minute papillæ on the surface of the head as in all other species, are prolonged in some individuals into slender muscular penes (Figs. 15, 16, *pe*).

There are from five to seven pairs of these organs on the ventral side of the head, corresponding to the same number of cephalic spermaries (Figs. 15, 16). That the penis is actually an outgrowth from the body walls is shown by the fact that its walls, like those of the body, consist of basement layer and circular and longitudinal musculatures. The organ is evidently capable of muscular contraction and may be considered a true copulatory organ.

In several of the specimens collected the penes were torn from their insertions in the body walls, and Brinkmann offers the suggestion that they may have been inserted into the ovaries of the females and held there to serve as spermatophores.

The female of this species has about 25 pairs of typical interdiverticular ovaries.

4. *Paradinonemertes*.—In *Paradinonemertes drygalaskii* Brinkmann ('16), of which two specimens are thus far known, the spermaries have suffered a still further reduction in number, being limited to two pairs of gonads situated immediately behind the brain and between the stomach and the lateral nerve cords (Fig. 17, *sp*). This is the extreme limit of reduction at present known among the nemerteans. These two pairs occupy the same position in the body as do the two anterior pairs in *Planktonemertes*, and are apparently homologous with them. The female of this species is still unknown.

5. *Pelagonemertes*.—It is in the genus *Pelagonemertes* that the spermaries show the greatest deviation from the primitive arrangement. In *P. brinkmanni*, a new species collected in the northwest Pacific Ocean, there are five to seven egg-shaped spermaries in a single cluster (Figs. 5, 7, *sp*.) on each side of the head in front of the brain. These open by a group of small genital papillæ situated ventrally on the antero-lateral border of each side of the head (Fig. 7, *gp*.).

In some cases the contraction of the tissues during the capture and preservation of the worms has ruptured the delicate cephalic walls and forced the spermaries quite outside of the body. They then appear as if they were external appendages on the anterior margins of the head.

The ovaries likewise suffer great reduction in number as compared with the forms previously considered, there being usually only six pairs of these gonads (Fig. 6, *ov*). Occasionally the number may be increased to seven or eight on one or both sides. The immature ovary contains as many as four to six or more small eggs, but as development proceeds most of these are engulfed as food material for the one, two, or occasionally three very large ova which reach maturity. The total number of eggs which one of these worms produces in a season is therefore hardly more than twenty to thirty.

In *Pelagonmertes rollestoni* Bürger ('09) finds likewise five or six pairs of spermaries (Fig. 12, *sp*) closely grouped on each side in front of the brain. The sperm ducts leading from each group

open close together on the ventral surface of the head and close beside the rhynchodeal opening, somewhat as described above for *P. brinkmanni*.

In *Pelagonemertes mosleyi* there are seven or eight pairs of ovaries, while in *P. rollestoni* the number may sometimes be reduced to four or five (Fig. 13, *ov*). As each of these ovaries produces but one very large egg, or occasionally two or three, the total number of eggs which mature in a season is hardly more than ten to twenty under the most favorable conditions. This number is in marked contrast to the hundred million which a single large female of one of the littoral species discharges in the space of a few days. The few however are so abundantly provided with nourishment that it is probable that the entire embryonic development is completed without the necessity of securing additional food. Since the oviducts are formed long before the maturity of the ova, it seems reasonable to assume that fertilization is internal, and it appears quite possible that the entire embryonic history is completed within the parent's body.

Summary.—The foregoing brief survey of the structural modifications of the body, and especially of the organs concerned in reproduction, which have recently been discovered in the pelagic nemerteans shows that the series may be looked upon as representing possible steps in an evolutionary series leading from the primitive condition of the well-known littoral forms to the highly specialized adaptations of organisms living as a sparse population in the vast areas of the open oceans. These modifications all tend toward a reduction in the number of gametes produced, correlated with increasing provisions for insuring fertilization and the survival of the relatively few offspring produced, and leading eventually to a true sexual dimorphism.

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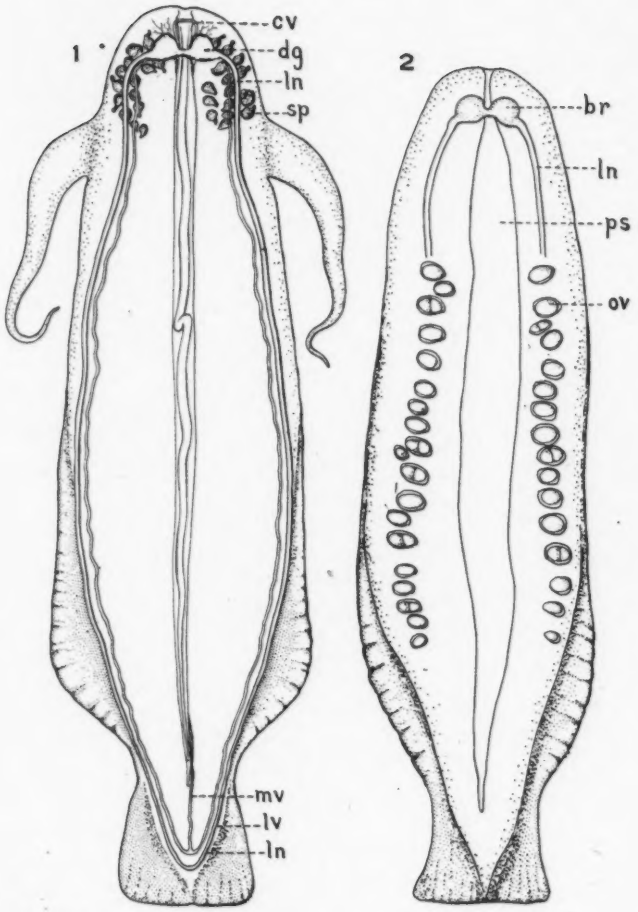
Explanation of Plate I.

Fig. 1. *Nectonemertes mirabilis* Verrill. Mature male, with well-developed tentacles and upwards of fifteen pairs of spermaries (*sp*), situated on the ventro-lateral borders of the head; *dg*, dorsal ganglion of brain; *ln*, lateral nerve; *cv*, cephalic blood vessel; *mv*, median blood vessel; *lv*, lateral blood vessel. × 6.

Fig. 2. Female of same species, with from sixteen to nineteen ovaries (*ov*) on each side of body. Each ovary contains but one large ovum, or sometimes two; *br*, brain; *ps*, proboscis sheath. × 6.



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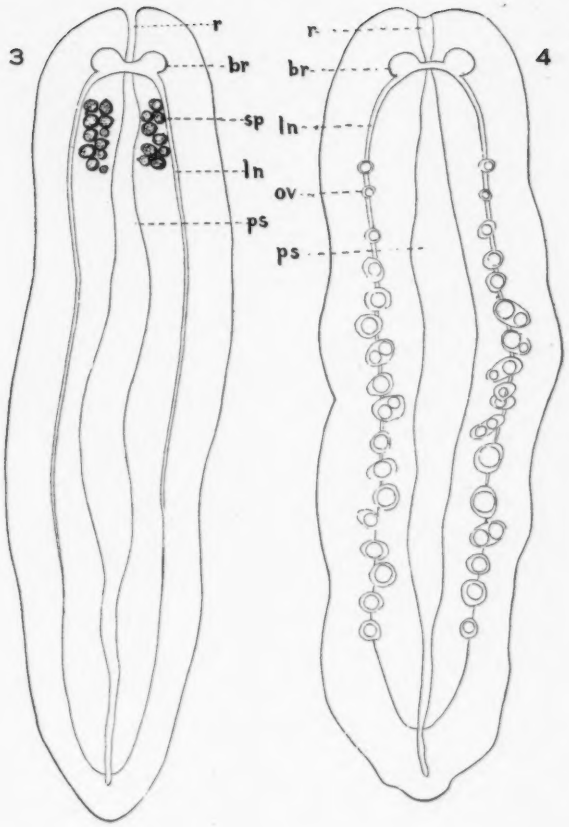
EXPLANATION OF PLATE II.

FIG. 3. *Planktonemertes agassizii* Woodworth. Outline of body of mature male with nine spermaries (*sp*) opening on the ventral surface on one side of the body immediately back of the brain and eleven on the other side; *r*, rhynchodeum; *br*, brain; *ln*, lateral nerve; *ps*, proboscis sheath. × 6.

FIG. 4. Outline of body of female of same species, showing the ovaries (*ov*), each with one or occasionally two large ova, situated beneath the lateral nerves on each side of the body. × 6.



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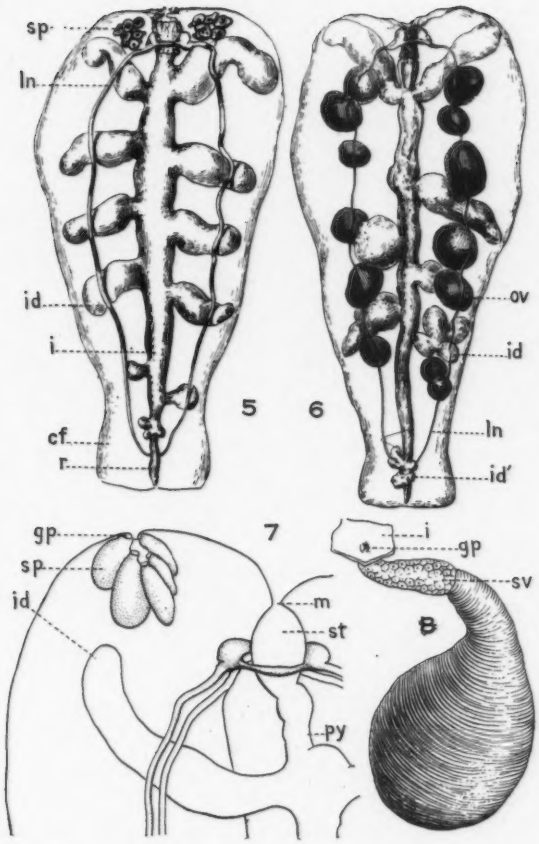
EXPLANATION OF PLATE III.

FIG. 5. *Pelagonemertes brinkmanni*, new species. Outline of body of male, showing the spermaries (*sp*) situated on the anterior margin of the head. The digestive and nervous systems are also shown; *i*, intestine; *id*, intestinal diverticulum; *r*, rectum; *ln*, lateral nerve; *cf*, caudal fin. × 6.

FIG. 6. Outline of body of female of same species, showing the six pairs of ovaries (*ov*), each with usually a single large egg. × 6.

FIG. 7. Anterior portion of body of same species, showing the five ovate spermaries (*sp*) which open on the anterior border of the side of the head; the genital openings here lie close together on blunt papillæ, but in some cases are more widely separated, due to different contraction of the adjacent tissues; *m*, mouth; *st*, stomach; *id*, intestinal diverticulum; *py*, pylorus. × 12.

FIG. 8. *Nectonemertes mirabilis*. A mature spermary, showing its thick muscular layer; *sv*, thin-walled seminal vesicle; *gp*, genital papilla. × 60.



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EXPLANATION OF PLATE IV.

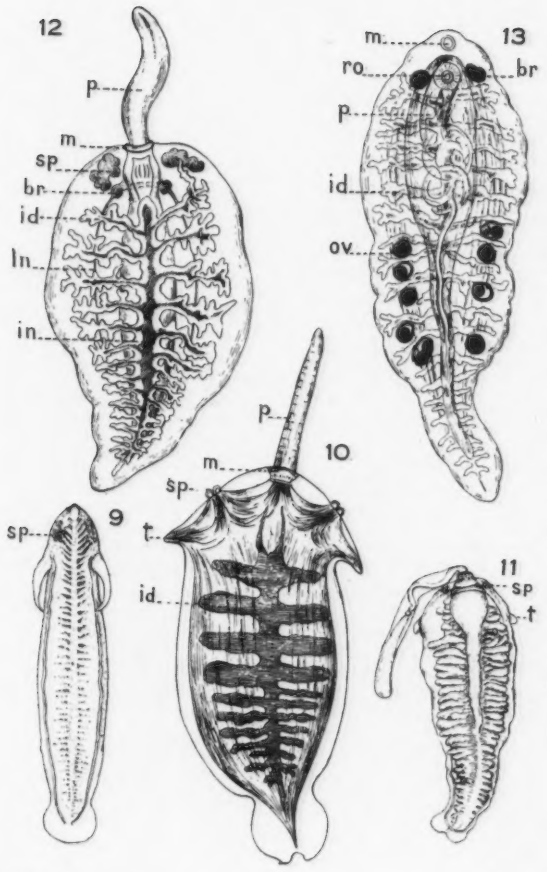
FIG. 9. *Nectonemertes grimaldii* Joubin. Male. Sketch of living animal, showing tentacles of medium size. × 1½. (After Joubin, '06.)

FIG. 10. *Balænanemertes chuni* Bürger. Sketch of male after preservation, showing the rudimentary tentacles (*t*) and the genital papillæ (*sp*) on which the sperm ducts open. × 8. (After Bürger, '09).

FIG. 11. *Nectonemertes chavesi* Joubin. From photograph of male with rudimentary tentacles (*t*). The spermaries (*sp*) are indicated on each side of the head. × 5. (After Joubin '06.)

FIG. 12. *Pelagonemertes rollestoni* Moseley. Adult male, with a single group of five or six closely placed spermaries (*sp*) on each side of the head; *p*, partially extruded proboscis; *m*, mouth; *br*, brain; *in*, intestine; *id*, intestinal diverticulum; *ln*, lateral nerve. × 3. (After Bürger, '09.)

FIG. 13. *P. rollestoni*. Female, showing the four or five ovaries (*ov*) on each side, each with from one to three ova; *ro*, rhynchodeal opening; other lettering as in figure 12. × 8. (After Bürger, '09.)



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Explanation of Plate V.

Fig. 14. *Nectonemertes minima.* Outline of head, showing position of the spermaries (*sp*) with their long genital ducts (*sd*) leading to the ventro-lateral surfaces of head; *m*, mouth; *br*, brain; *t*, base of tentacle. × 24. (After Brinkmann, '16.)

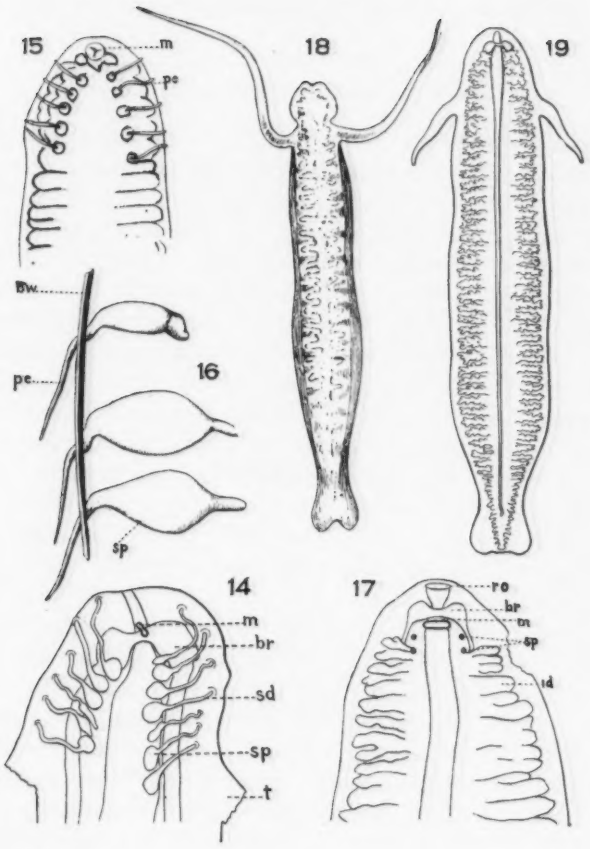
Fig. 15. *Bathynectes murrayi.* Outline of anterior portion of body, showing the five pairs of protruding genital ducts (penes, *pe*); *m*, mouth. × 6. (After Brinkmann, '12.)

Fig. 16. Same species. Outline of three of the muscular walled spermaries (*sp*), showing the genital ducts (*pe*) protruding from the body walls (*bw*). × 12. (After Brinkmann, '12.)

Fig. 17. *Paradinonemertes drygalskii.* Outline of anterior portion of body of male, showing the two pairs of spermaries (*sp*) behind the brain (*br*); *ro*, rhynchodeum; *m*, mouth; *id*, intestinal diverticulum. × 12. (After Brinkmann, '16.)

Fig. 18. *Nectonemertes mirabilis.* Sketch of living, sexually mature male with fully developed tentacles. Length of body after preservation 19 mm. × 4. (After Bürger, '09.)

Fig. 19. *N. pelagica.* Outline of body of sexually mature male. × 6. (After Cravens and Heath, '06.)



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A STUDY OF THE COMBINED ACTION OF X-RAYS AND OF VITAL STAINS UPON PARAMŒCIA.

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It has been definitely recognized that X-rays exercise injurious effects upon both vegetable and animal forms of life and, moreover, that the adult tissues possess a variable absorption capacity for this form of energy. On the other hand, experiments conducted for the purpose of ascertaining the nature of the reactions of bacteria to X-rays have generally proved negative. In marked contrast to seeming bacterial immunity, unicellular organisms show a marked degree of susceptibility.

During the spring and summer of 1916, through the courtesy of the Research Laboratory of the General Electric Company at Schenectady, the author was enabled to make use of X-ray energy in a prosecution of the study of the action of vital stains upon various forms of animal life. These experiments were begun with paramœcia. The investigation comprised, first, the study of the action of vital stains upon these forms of life; secondly, of the effect of X-rays acting alone; and lastly, a study of the reaction to X-ray energy while under the influence of these vital stains. The stains used for this purpose were Nilblau sulfat (Gruebler), Alizarinblau (S), Trypanblau, Isaminblau, Nilblau chlorhydrat, Trypanrot, Dahlia (Gruebler), Neutral red, Anilin red (Sudan III. oil), Janus green (Eimer and Amend), Methylene blue (B.X.) (Merck). These stains were in the form of dry powders. Solutions were prepared with tap water. It had been previously ascertained that this tap water contained no substances injurious to the organisms either at the time of raying or thereafter. The solutions of the stains were freshly prepared for each experiment. In the majority of instances a stock solution consisting of 0.001 gm. of stain to 200 c.c. of water was used, a subsequent dilution of this stain being made before each experiment. This stock solution was not kept for a period

longer than twenty-four hours. Cultures of the paramœcia were added to graded dilutions of the stain with the object of ascertaining the maximum degree of concentration compatible with the life of the organism. The absorption of the stain by the organism was demonstrable through the appearance of stained globules within the body. It was ascertained early in the experiment that this absorption would progress, if undisturbed, to such a degree that the death of the organism resulted. When this phenomenon was about to ensue the motility of the organism became very sluggish, finally ceasing altogether. The elongated, elliptical body-shape was replaced by a spherical form, while the nucleus quickly became deeply stained. It was found not to be possible to bring about a staining reaction of the nucleus without causing the death of the organism. Indeed, the latter became a safe index of over-absorption of the stain.

For the purpose of testing out the absorption capacity for the stain compatible with the life of the organism, 0.5 c.c. cultures of the paramœcia were placed in ordinary watch glasses, to which were added varying amounts of the solutions of the stains. In the preliminary experiments these proportions ranged from two volumes of culture to twelve volumes of stain, to eight volumes of culture to two of stain. The cultures were then carefully attended during the succeeding days with the view of providing sufficient oxygen and to prevent evaporation. A reference to a typical experiment of May 31, 1916, A.M., will be sufficient to give an exact idea of this procedure. For this experiment a stock solution of neutral red in the strength of 0.001 gm. of the dry stain of 200 c.c. water was used.

With such stains as methylene blue and dahlia the absorption capacity of the organisms was so great that it was difficult even in greatly diluted solutions to prevent the staining of the nucleus. With trypanblau, neutral red, and trypan red, on the other hand, the capacity of the organisms for the stain seemed to have a more definite though not absolutely fixed limit. In these instances it was ascertained that, when the cell-body had taken up its maximum carrying amount of the stain, not injurious to the activity of the organism, subsequent immersion over a relatively long period of time in a very greatly diluted solution

Experiment May 31, 1916, A.M.	Observations of June 1, 1916, A.M.	Observations of June 2, 1916, A.M.
Series No. 1, Culture 2 parts (by volume), Stain 8 parts (by volume)	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.
Series No. 2, Culture 2 parts (by volume), Stain 7 parts (by volume)	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.
Series No. 3, Culture 2 parts (by volume), Stain 6 parts (by volume)	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.
Series No. 4, Culture 2 parts (by volume), Stain 5 parts (by volume)	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.
Series No. 5, Culture 2 parts (by volume), Stain 4 parts (by volume)	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.
Series No. 6, Culture 2 parts (by volume), Stain 2 parts (by volume)	Series No. 6, paramœcia sluggishly active, few motionless with stained nuclei.	Series No. 1, paramœcia spherical in shape, motionless, nucleus stained.
Series No. 7, Culture 3 parts (by volume), Stain 2 parts (by volume)	Series No. 7, all active.	Series No. 7, all active.
Series No. 8, Culture 5 parts (by volume), Stain 2 parts (by volume)	Series No. 7, all active.	Series No. 7, all active.

of the stain did not result apparently in a further absorption. The experiments demonstrated, moreover, that the various stains possessed a differing degree of toxicity for these organisms similar to that which had been noted by Lewis in his study of the action of vital stains on bacteria.

Practically it was found to be more convenient to stain organisms for a period of from one and a half to two hours in a solution of a degree of concentration somewhat greater than that which could be tolerated without injury for a period of twelve hours. At the expiration of this staining period the organisms were transferred to the diluent tap water in the proportion of ten volumes of the water to one volume of the organism and stain and studied during the succeeding days. Through an empirical process of experimentation the approximate degree of concentra-

tion tolerated by the organism followed by a dilution as above was ascertained. In the instance of trypanblau, trypan red, isamine blau, and neutral red, this was found to be eight volumes of the water solution of the stain to two of the culture. The stock solution contained 0.001 gm. of the dry stain to 200 c.c. water. Staining of the paramœcia cultures from one and one half to two hours at the room temperature brought about the appearance within one half hour of a deep globular coloration of the cytoplasm of the organism. The subsequent dilution of this stained culture, through the addition of ten volumes of water to one of the culture, prevented subsequent injury, so that the vitality of the organisms remained unimpaired for a period of eight days. The nucleus did not become stained nor was the motility lessened. Ordinarily, the specimens were not studied for a period longer than eight days. With a few, however, observation at the expiration of fourteen days demonstrated still actively motile paramœcia with unstained nuclei. Beyond these limits no effort was made to ascertain either the varying degrees of rapidity of absorption for the different stains or the exact limit of absorptive capacity of the organisms for any particular stain. The dilutions above-mentioned were arbitrarily selected, since with these as a constant, the most marked reactions to X-ray energy were obtained.

The next step in the experimentation consisted of a determination of the amount of X-ray energy necessary to cause the death of unstained organisms. The source of energy was a special Coolidge tube actuated by 35 K.V. with a current strength of 2.0 milliampere and cooled by an airblast. Since the total diameter of the tube was only 7.0 cm. the paramœcia cultures could be placed in ordinary watch glasses at a distance of 8.5 cm. from the center of the target. They were protected from the heat rays arising from the tube by means of three spaced-layers of carbon paper. Numerous experiments showed that there was hardly any loss through evaporation during the raying.

A quotation from the notes will illustrate the general experimental results observed. On the morning of May 5, 1916, a series (*A*) of six cultures, each consisting of numerous unstained paramœcia, was rayed under the conditions mentioned above

during a continuous period of thirty minutes. At the expiration of this exposure the motility of the organisms had become appreciably slower. No changes, however, could be observed either in the character of the cytoplasm or of the nucleus under a magnification of 400 diameters. On May 7, 1916, the observation was made at 2:30 P.M. that a few of these paramœcia were still active though they had lost a great deal of the rapidity of action of their cilia. The majority were motionless and rested upon the bottom of the glass. These had assumed a spherical shape, while in them there could be detected unmistakable evidences of degeneration of both nuclear and cytoplasmic material. In the unstained specimens these facts were demonstrated through a loss of their translucent character and by the granular appearance of the protoplasm. Series *B* consisted of six cultures of paramœcia which were rayed under conditions similar to those of series *A* for a period of twenty-six consecutive minutes. At the termination of the exposure all of the paramœcia were vigorously active. There was no indication of the slowing down of ciliary motion. A study of the specimens forty-eight hours thereafter demonstrated a still vigorous motility. No dead paramœcia could be found.

By this method of varying the length of the exposure to the X-ray energy, the other conditions of the experiment remaining constant, it was ascertained that continuous raying during a period varying from thirty to forty minutes was necessary to bring about, upon the day following the raying, a complete sessation of motility and unmistakable evidences of degeneration. It was not possible, however, to cause protoplasmic changes immediately following the raying in either the nucleus or the cytoplasm. These could be made out first only after a twenty-four hour interval after the raying had elapsed. Beyond this no further inquiry was made to ascertain the cytological cause of cessation of motility. Similarly through repeated experimentation, it was found that exposures of from ten to twenty minutes duration exercised no effect whatever, either immediately or subsequently, upon either the motility or the vitality of the organisms. A study of these rayed organisms was not conducted, however, throughout a period greater than eight days after the raying.

The next and final step in the experiment consisted of a study of the action of the rays upon stained cultures of paramœcia. The staining of the organisms was carried out according to the method which I have detailed above. The energy utilized was that which has also been given above. A reference to the experiment notes will give an idea of the results obtained.

On May 10, 1916, series *C*, consisting of six paramœcium cultures, was rayed beginning at 2:00 P.M., each for a period of 12.5 consecutive minutes. These cultures had previously been stained for 105 minutes in a trypanblau solution of the strength 0.001 gm. of the dry stain to 220 c.c. tap water, of which mixture four volumes were added to one volume of the culture. The staining was begun at 11:15 A.M., and the raying at 2:00 P.M. At the expiration of the raying period, all of the organisms were very sluggish in action. At the expiration of forty-eight hours all were dead. Controls to these experiments were conducted in which the unstained paramœcia were rayed for an equal time, and paramœcia were stained during an equal time. In both instances the organisms were unaffected. In one series (*B*) the unstained paramœcia were rayed for a period of 12.5 consecutive minutes and in *C* during a period of thirty consecutive minutes. Forty-eight hours afterwards the unstained cultures were still alive and vigorous but in series *C* most of the paramœcia were dead, a few, however, remaining sluggishly active.

By a continuation of the experiment along this general line, through increasing the concentration of the stain, it was found possible to cause the death of the organisms with an exposure varying from 2.5 to 5 minutes. A reference to the experiment notes of May 18, 1916, verifies this fact. On this day series *A*, consisting of six cultures of paramœcia, was stained with trypanblau for two hours (stock solution 0.001 gms. to 200 c.c. tap water, diluted in the proportion of 2 volumes of culture to 8 of stain). These were then rayed for five consecutive minutes, beginning at 10:42 A.M. At 11:00 A.M. a few of the paramœcia were observed to be active, though this activity was considerably slowed. The majority, however, were motionless. Forty-eight hours later a still greater number of paramœcia were dead. The nucleus had assumed a dark bluish color, the cytoplasm had

become opaque and deeply blue in color, and the organism had assumed a spherical outline. A few, however, were still sluggishly active. On the succeeding day, these also died. The control specimens which were treated to the stain in the same manner, but which were unrayed, were still alive on May 26, eight days afterward. On May 22, six other cultures, series *F*, were rayed 2.5 consecutive minutes after treatment with trypanblau stain prepared as in series *A*. They had been subjected to this stain for two hours previous to the raying. Very few of these paramœcia were alive on the succeeding day. The majority demonstrated a stained nucleus, spherical outline, and loss of ciliary activity. Controls to this series, however, some of which were rayed unstained for a period of ten minutes, and others stained from 11:15 A.M. to 1:41 P.M., but unrayed, were still alive seven days later, and, judging by their activity, had been unaffected.

In general this is the result of the action of X-rays upon vitally-stained paramœcia. The quantity of energy necessary to inhibit the activity of unstained paramœcia varies from sixty to eighty milliampere minutes under the conditions of technic given above. When the cultures are stained, as with trypanblau in the concentration mentioned, the amount of energy required to inhibit their activity is reduced to from five to ten milliampere minutes. There is however, considerable variation within certain limits in the susceptibility of the cultures to X-ray energy and also in the rapidity with which they absorb stains.

So far as could be observed upon these specimens the cause of death was due to an assumption of stain by the nucleus. This causative agent appears to be constant both in the stained but not rayed specimens and also in the stained and rayed specimens. It would appear as if the nuclear membrane were normally impervious to the colloid stain until the degree of concentration of the stain in the cytoplasm became great enough to overcome this resistance. One might assume that X-rays alter this permeability thus permitting the stains to diffuse readily into the nucleus.

Solutions of trypanblau, trypan red, neutral red, and of dahlia when exposed to X-ray energy are not fluorescent nor is there

a loss of color reaction of solutions from prolonged exposure to the rays. Very careful histological examination under high-power magnification has failed up to the present to detect a change in the color of the absorbed stain after raying, or to give evidence of a redistribution of the stain in the cytoplasm. Moreover, a series of experiments in which normal paramœcia were stained by trypanblau solution which had previously been rayed for periods varying from five to thirty minutes, failed to demonstrate either an injurious effect of the rayed stain upon the organisms or an increased rapidity of absorption by the organisms of that stain. The cause for the increased susceptibility of the organisms to X-ray energy is to be found apparently in some factor which is operative only when X-rays act on the cells in the presence of the stain.

ALTERNATE PHASES IN FOLLICULINA.

E. A. ANDREWS.

As long ago as 1858 it was independently affirmed by Wright (7) and by Claparede and Lachmann (6) that the sedentary marine infusorian once known as Freia, but called now by the more prosaic term, the bottle animalcule, *Folliculina*, could reduce itself to a more simple larva-like form and then swim free, subsequently to make for itself a new dwelling in which to differentiate again into the perfect form.

So great was the difference in structure that the free swimming form was regarded by Daday (3) as a new genus to be placed in a family quite different from the family of Stentors in which the adult sedentary *Folliculina* belongs.

Even as late as 1916 Sahrlage (4) after much study of *Folliculina* denies the reality of any process of alternation of differentiated and dedifferentiated phases in *Folliculina*. He also denies the credibility of the evidence that *Folliculina* is found in fresh waters as well as in the sea.

In both these negations he is shown to be wrong by Penard (5) who studied fresh water Folliculinas and describes the transformations from one phase to the other back and forth.

However, both these authors, overlooked the fact that in 1914 (1, 2) the same alternation of sedentary and free swimming phases early claimed for *Folliculina* in Europe had been found in American waters.

The present paper will serve to reaffirm the reality of this alternation in Folliculina and to emphasize its fundamental nature.

Folliculina being the most specialized of the highly complex Stentors presents in its anatomy an unusually high grade of complexity, while its ability to fabricate a complex dwelling by secretion is the acme of accomplishment among the ciliated protozoa.

Under the conditions elsewhere described (1, 2) *Folliculina*

passes readily back and forth from more complex sedentary to more simplified free-swimming phases of form and activity.

In the sedentary phase the animal occupies a house or case from which it may protrude two very long ligulate lobes that make its feeding apparatus so effective. In this phase the animal presents the maximum differentiation and is capable of division, as described in part by Mobius (9) and more in detail by Sahrlage (4). This is the adult or perfect phase. In the free-swimming phase the animal lacks the feeding lobes, the mouth and the special organ for attachment and it is in fact a simplified, retrograded or dedifferentiated form which some have called a larval form. It is, however, the free-swimming form that fabricates the house which it will occupy when it has differentiated into the perfect form, from which state it may again retrograde back into the simplified free-swimming stage and again leave its house.

Briefly, the general structure of these two forms is as follows: The free-swimmer is cylindrical, capable of great extension and contraction with spiral and lateral bendings. It moves by means of about 100 lengthwise lines of cilia. At the posterior end the cilia are absent over an area within which is a complex, problematical organ into which the myonemes converge. At the anterior end there is a very small, nearly circular spiral of membranells which though active seem to have no special use. Where the infundibulum and mouth might be expected there is a small microscopic vestige of no conceivable use. The animal captures no food. The food that may be inside of it was obtained in the previous phase when the feeding lobes and mouth were present. Essentially this free-swimmer is the adult broken loose from its former attachment to the bottom of its house or case and dedifferentiated to the extent of entire resolution of its lobes, pharynx, and hypostome. The only vestige of all its former feeding apparatus being the above-mentioned minute ectosarcal cup and the single limb of a spiral hypostome.

On the other hand the anatomy of the adult sedentary form is more complicated. In addition to the long lines of cilia and pigment underlaid by very highly specialized myonemes, there is at the posterior or foot end a special organ of fixation to the

bottom of the house and at the oral or anterior end the remarkable lobes, arms, or flat ribbon-like extensions of the body which have been likened to the ears of a rabbit. These like the rest of the body are exceedingly pliant and almost always in active movement. Where the two arms or lobes arise from the main mass of the body a funnel leads into the interior and ends in a mouth with complex activities. In addition to the longitudinal lines of cilia which run on both the outer and inner faces of each lobe there is a very highly organized band of membranells. This starts near the edge of the funnel ventrally on the right side, runs out along the entire inner face of the right lobe almost to its tip, then returns parallel to itself along the dorsal part of that same lobe to the main body, makes a dorsal course around the funnel to the left side and out along the dorsal edge of the left lobe almost to its tip, then back parallel to itself near the ventral edge of the left lobe to the edge of the funnel down which it goes in a spiral of about 2 turns, ending very near the cytostome. On the left ventral face of the exterior of the body there is a definite region which opens and closes as the functional anus.

While the two phases thus differ remarkably in the high specialization of the adult feeding apparatus as compared with its nearly obliterated condition in the free-swimmer, both phases have essentially the same character of nucleus, namely one long many-lobed moniliform macro-nucleus accompanied by very many minute micro-nuclei. The function of the free-swimmer is not only to transport the animal from one place to another, often for considerable distances, but also to build up the house in which it will live after it has become differentiated into the adult form.

The method of making the house will be described elsewhere but it consists of a series of activities; first, the selection of the site; second, the making of the sac or bottom; third, the making of the spiral tube; and finally, the finishing of a lip around the orifice on top of the tube. After all this is accomplished, the free-swimmer inside the case that it has built, rapidly differentiates into the adult form, capable of stretching out of the case and getting its food. It is this adult form which may later dedifferentiate or retrograde into a free-swimmer and break loose and escape from the house and later construct a new house somewhere else.

The times consumed in the various elements of this alternation of phases vary very greatly, being hastened by high temperatures in general. Often the animals that have been feeding adults during the night pass into the swimming form in the morning, settle down toward the middle of the day and transform into adults again before night so that an entire wave of rise to the adult and recession to the swimming form and rising again to the adult may be about 24 hours. However, in some cases an entire alternation was accomplished in perhaps as little as 6 hours.

The following anecdote relating to a single individual folliculina acting under unusual conditions may serve to illustrate the pertinacity with which these alternating phases are adhered to and to raise a number of questions which it would require experimentation to solve.

August 28, 1914 which was very near the end of the season for the occurrence of *Folliculina* in the Severn River, a number of perfect animals in their houses were placed in a hanging drop over water in a hollow slide for the purpose of seeing how they retrograde into the free-swimming form. One group had 17 or 18 perfect cases, another had 5.

By some accident one of these cases had the tube jammed at the tip so that it was closed off. August 29 at 7:50 A.M., temperature 75° F., the folliculina in this tube which from its color was evidently an old one, not recently formed, was found to be in a late stage of reduction of the arms in the process of becoming a free-swimmer (Fig. 1). It revolved on its foot as normal, with reversals of direction and the arms had been, as it were, melted down to a castellated ridge or membrane while the long complex adoral zone was now but a semicircular band running along the edge of the very obliquely truncated end of the body, opposite to the above elevated ridge. At 9:50 the arms were reduced to nothing and the folliculina was ready to break loose as a free-swimmer with normal spiral adoral band (Fig. 2). This larval stage then broke free from its foot and proceeded to go out of the tube as is normal, but was prevented from emerging by the closure of the tube near its tip. Then began a long series of advances and retreats in which the free-

swimmer vainly tried to force itself out of the tube end, but did not succeed in boring its way out with the narrower tip of the body and all possible efforts (Fig. 3). After two hours and a half of this free-swimming life inside of the case, the free-swimmer settled down to the bottom of the case and became attached there by its foot end again, thus settling down as it naturally would have done after the same interval of time had it, as normal,

FIG. 1.

FIG. 2.

FIG. 1. *Folliculina* trapped inside closed case, dedifferentiating its lobes at 7.50 A.M., August 29, 1914.[1]

FIG. 2. Same at 9.50 with lobes gone and free-swimming form completed.

swum free through the water to some distant point of contact and selected a new solid surface to become attached to, far from its old dwelling.

From 12:50 onwards the newly attached larva at the bottom of the case was seen to be reconstructing its lobes (Fig. 4) and this process was completed at 10 P.M. In this process of making lobes (Fig. 4) the usual series of phenomena took place just as is the rule after a free life and formation of a new tube; but here the old tube was used to dwell in and no new tube was formed.

[1] *Explanation of Illustrations.* All sketches outlined with camera lucida, Zeiss, 4, D, that is enlarged about 700 diameters and then reduced to one third in diameter.

All sketches are successive views of one individual *Folliculina*.

In making lobes the old adoral band of membranells sank down into the interior and was apparently entirely melted away during a remarkable loss of organization of all the terminal region of the body accompanied by especial internal circulation of the now very fluid endoplasm, rapid currents passing dorsally from the foot end up to the peristomal end, across that end and down again to the foot ventrally to complete a circuit. The appearances sug-

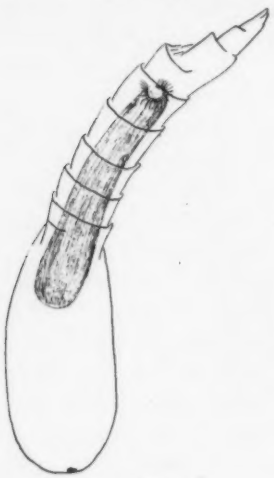

FIG. 3.

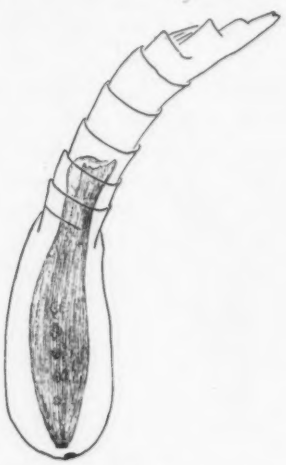

FIG. 4.

FIG. 3. Same at 12.30 swimming in vain attempts to get out.

FIG. 4. Same at 4 P.M. again attached by new base inside case and with new lobes differentiating. A stage like that in Fig. 1 but going toward differentiation and not the reverse.

gest that the usually well organized and rather rigid anterior end of the animal as well as much of the interior rather suddenly breaks down into a fluid state as if a solid were melted, or a gell changed to sol, and then this begins to rotate violently from unknown causes. The animal now is a cone of stiffer ectosarc with ciliated lengthwise bands and subjacent myonemes attached at end, which is tip of cone, while the base of cone is oblique and liquid out to a mere superficial pellicle, apparently (Fig. 4). This oblique soft face has lost all myonemes and cilia as well as the former rigid adoral band of membranells and the pigment patch.

This oblique cone-base then elongated down one side of the cone like a candle that is gutted down one side, but meanwhile the edges of the soft base rose up more and more as walls like the edges of end of a burning candle. The elevated walls were irregular and fantastic at times, with castellated edges. One side was greater than the other and for long one of the lobes which is the left, was greater than the other. But it is not the elongation of the edges of the cone base that makes the lobes, so much, but the actual splitting down of the base internally into right and left halves. That is, the soft end divides more and more to form a deep groove between the tips of the lobes and so the bases of the lobes are produced more and more down into the interior till finally the two lobes are nothing more or less than the right and left halves of the basal third, or more, of the original cone separated from one another by a deep median space. The new adoral zone that is to follow the edges of the arms arises at an early stage and seems to have no connection with any previous formation but to be differentiated *de novo* from the softened and disorganized terminal and lateral areas. The adoral band starting at one end from within the minor or right arm rudiment, or papilla that is to be its tip, sweeps in a circular arc dorsally and then along the left side central to the rudimental tip of the larger left arm to then pass down the ventral face of the animal where it extends very far toward the apex of the cone. As the animal becomes twisted spirally and has the habit of rotating and of changing the direction of rotation from time to time, it becomes difficult to ascertain how the band is completed, but it is evident that the tip of the band nearest the foot burrows inward into the protoplasm as the future spiral within the peristomal funnel and ultimately acquires a mouth or cytostome at its innermost termination; but in proportion as the two lobes are separated from one another as halves of the animal's body, the two lateral sides of the hypostome curve (Fig. 5) are pulled out as lateral loops that run up and down each arm till the ultimate course of the membranell band is that of two long inverted Us or tuning fork curves connected dorsally by a short dorsal part of the curve, beginning abruptly on the inner face of the base of the right lobe and ending at the opposite

base of the left lobe as that inner spiral that runs within the animals peristomal funnel to terminate at the cytostome.

All the complex organizations having been accomplished in usual order, there resulted at 10 P.M., Aug. 29 (Fig. 5) a creature with great powers of extension and with the anterior third of the body split into two very mobile and responsive arms bearing the collecting membranells destined to produce in the water outside the case such powerful currents as rotifers, bryozoa and the close relatives of *Folliculina*, Stentors, make to bring food particles within control of the selective mechanisms near the mouth. As this individual with its newly formed feeding and

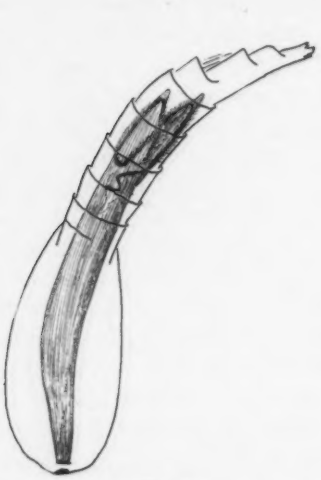

FIG. 5.

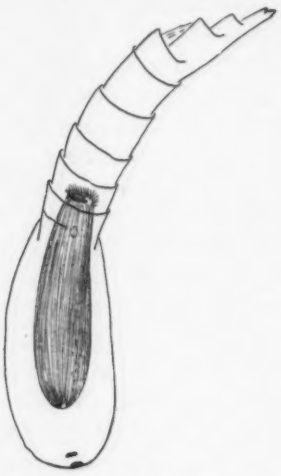

FIG. 6.

FIG. 5. Same at 10 P.M. with fully differentiated lobes, mouth, and feeding apparatus, but with lobes not fully expanded inside closed tube.

FIG. 6. Same August 30, 6.45 A.M., now dedifferentiated into swimming stage again, with two scars of former attachments to base of sac.

responsive organs elongated for the first time, as is normal when first reaching out of the tube it had made before possessing such organs, it, in this case of closed up tube, came to a physical resistance that it could not overcome. Very many trials were made in attempts to complete the normal expansion from mouth of tube; sometimes one lobe alone was thrust up into the closed

tube, the other being bent back alongside of the body like the ear of a lop-eared rabbit; sometimes both lobes were thrust forward. With repeated contractions toward base of tube and repeated expansions and stretchings out, much time was spent in the vain endeavor to complete the expansion which alone would lead to function of the feeding apparatus.

Sometime in the night of August 29 this series of trials must have come to an end, for at 6:45 A.M., August 30, it was found

FIG. 7.

FIG. 8.

FIG. 7. Same at 8.57 when the anterior part had succeeded in forcing its way out of tube, but major part remained inside nearly severed from anterior moity.

FIG. 8. Same at 9.09 showing revolution of anterior part, twisting connection with posterior part inside tube, and healing over of torn base of anterior part.

that these useless lobes had been resorbed or dedifferentiated and again the animal was in the form proper to a free-swimming phase (Fig. 6).

When this new free-swimming phase broke loose from its foot

attachment there were two scars left on base of tube sac, one for each of the two secessive periods of attachment of the animal to the base of the same dwelling.

Upon swimming up to the top of the tube to escape, as is normal, the free swimmer now met with resistance as before but for some reason the tube was not entirely closed as it seems to have been the day before, possibly the force exerted by the pushing of the lobes of the animal the day before had some effect in changing the character of the closure of the tube. At all events the free swimmer was finally able to force its front end out of the tube through a minute orifice on one side back of the tip so that by 8:45 it was seen escaping from the tube (Fig. 7). However, the escape was but incomplete since the hole was minute and the animal did not succeed in propelling its entire length through; on the contrary, more than half its bulk remained behind within the tube (Fig. 7) and the body was constricted to a very narrow waist when passing through the narrow hole, and was, as it were, cut almost into two with a very narrow pedicle connecting the swimming part outside the tube with the enlarged part within the tube. What abnormal conditions here prevailed it was not determined, but one factor in the failure to progress completely out of the tube seems to have been the abnormal state of the foot end. This swelled up into globular form and lost much of its normal organization, receding into a more fluid phase. The contents slowly revolved in flow and the protoplasm seemed more dead than living. Nevertheless the cilia continued to cause the mass to revolve for three and a half hours before dissolution of the ectosarc resulted.

Meantime, for nearly two hours, the anterior part of the animal now outside the tube continued to swim with its numerous rows of cilia and exerted strain upon the part within the tube; this gradually led to the pulling out of a lengthening isthmus or cylindrical waist between the active outside and the passive inside swollen part. The base of the outside part became pinched off nearly to complete severance from the rest. It formed an oblique base of ragged form sending out pseudopodial processes but ever at one corner, continuous with the hind part

of the animal by a very slender strand that reached through the hole in the tube to the rest of the animal still imprisoned. Within the tube this slender strand became twisted as the outside part swam in its usual spiral revolving way (Fig. 8). Gradually, this dark green strand was at first twisted, drawn out longer, made

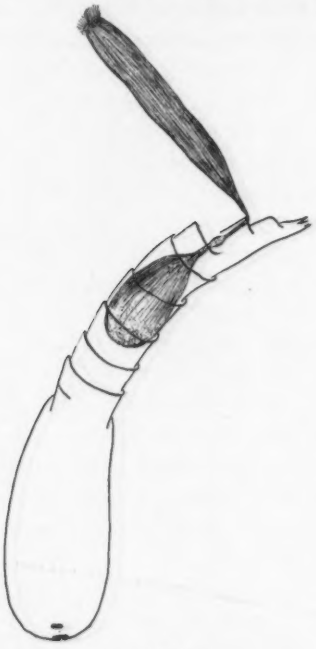

FIG. 9.

FIG. 10.

FIG. 9. Same at 10.05 when the anterior part swimming powerfully stretches out both its own body and the connecting strand that binds it to posterior region within tube.

FIG. 10. Same at 10.10, showing change of direction of swimming that tends to wind the connecting strand about the tube.

an ever lengthening and very slender string connecting the active outside animal with its dying foot (Figs. 8, 9, 10, 11). The animal revolving swung its head end in wide circles while the slender string held its other end firm to the hole in the tube. Moreover, the direction of pull exerted by the combined stroke of the many cilia was changed so that the strain now pulled

the string out at right angles to the tube (Fig. 9), now parallel to the tube length. Within the tube the string was also pulled out long (Fig. 9) but did not break loose either from the dead swollen foot mass nor from the swimming part. It is to be remarked that the ragged base of the free animal had by 10 A.M., that is, in about an hour's time healed over so that it was no longer ragged, oblique, provided with projections and attached

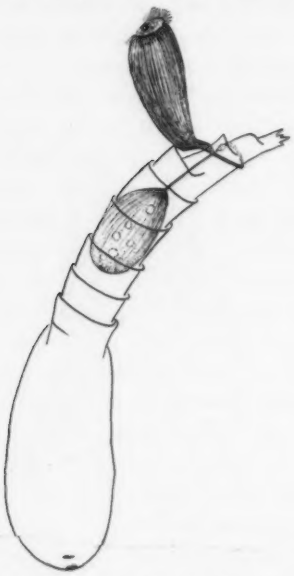

FIG. 11.

FIG 12.

FIG. 11. Same at 10.40. The strand wound about the tube brings base of swimming part against tube and the swimming form contracts to take on the sedentary phase.

FIG. 12. Same at 11.40. The free-swimming stage having terminated, the anterior part has secreted a sac attached to old tube; while the posterior part is disintegrated and being eaten by scavengers within the tube.

by one corner only to the string, but was smoothly finished as a cone with its central part passing smoothly forth (Fig. 9) as the cylindrical slender string of protoplasm which would not break. With the elongation of this strong filament of firm protoplasm, the free animal had more and more wide excursions bound by this

tether, and came to swim entirely around the end of the tube, pulling its cord with it till it became wound up like any larger animal so tied (Figs. 10 and 11). Fig. 10 shows the result of an excursion about the end of the tube in which the string was drawn out very fine and long, but later the animal relaxed and ceased to swim vigorously so that the string shortened and thickened somewhat. Its elasticity pulled the body back toward the tube. The effete mass within the tube still seemed alive on the surface at 9:25 as it had myoneme bands, and cilia that caused it to revolve, but by 10:32 it had come to rest. At 10:40 (Fig. 11) the animal ceased to struggle and now having spent the normal time of a free-swimmer in the swimming activities thus carried on by the anterior part with the limitations of tethering to the imprisoned posterior part, the internal conditions of fixation and tube building had become ripe for expression. The base of the external moity flattened out on the tube surface and acquired attachment to the tube after the manner of a nascent foot, while at the same time breaking off the long-lasting tether or strand that had held it to the posterior moity within the tube. Of the old animal was now left the anterior part which proceeded to make a new dwelling on the outside of the old tube (Fig. 12), the swollen posterior part within the old tube which became more and more a rounded dead mass to be destroyed by protozoan scavengers and the slender connection string or middle of the old body which partly inside and part outside the tube soon was lost to view, as if disintegrated or eaten by scavengers.

The fate of the dead posterior was as follows: A rounded mass (Fig. 12) containing portions of the original macro-nucleus was attacked by protozoa which forced themselves against it and indented it as if it were jelly-like with more firm exterior though the original myonemes and colored bands had disappeared. At 11.53 the scavengers entered into the original foot end of the mass which now had become liquified or disintegrated where attacked. At 1 o'clock the mass was broken up into fine granular matter (Fig. 13) scattered about by the movements of thirteen scavengers and into certain refractive shells, apparently representing lumps of the macro-nucleus of greater firmness eaten out on one side by the scavengers which

pushed them about as they ate into them. By 8 o'clock the next morning (Fig. 14), August 31, nothing visible was left to represent the old dead posterior end except a few of the scavengers, six in place of thirteen, and these moved sluggishly, and the following day only dead remnants were left, imprisoned in the

FIG. 13.

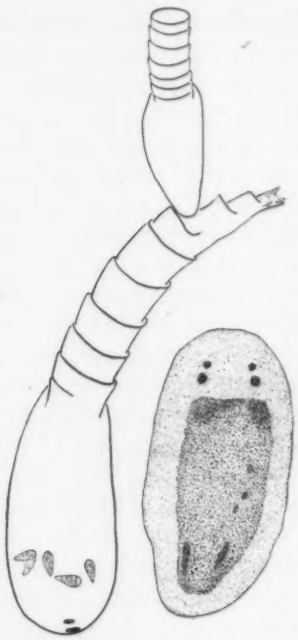

FIG. 14.

FIG. 13. Same at 12.59 after the sedentary form has completed a spiral tube and has assumed the mushroom form preparatory to finishing the secretion with a terminal lip. The old posterior part within tube nearly all eaten up by scavenger protozoans.

FIG. 14. Same August 31, 8 A.M. after a planarian (which is indicated below on right), had sucked out the sedentary folliculina when about to differentiate into the perfect form.

old tube base, as greenish detritus. The scavengers seemed to be the ciliated protozoon, *Urotricha*.

The anterior living part of the animal, however, outside the tube while attached to the tube continued to advance in the

normal cycle of rhythmic activities characteristic of an entire animal; that is, it proceeded to make for itself a new dwelling with all the developments of form that underlies that architectural result. To be sure this new dwelling was small as was the bulk of the anterior half animal that made it and it was not as perfect as normal tubes in the open, but yet it was merely lacking in finish and some perfections of proportion and in no wise deficient in fundamental traits nor more unfinished than many dwellings of whole animals when made in conditions of poor food, etc., incident to long stay in a hanging drop.

The process of making the tube was continuously observed for nearly one hour during which time a dozen camera lucida sketches of successive phases were made. In making the dwelling the new animal which had regenerated from the anterior part of old one followed the traditional sequences as below described.

The dwelling or case of Folliculina comprises a sac or attached swollen part and a long tubular continuation which is ornamented by a spiral ridge (Fig. 1). The orifice at the end of the tube is completed normally by a very pretty everted lip, made after the spiral part is finished. In this case of dwelling making, the anterior part animal having become attached, proceeded as if entire, assuming for its attached and adjacent areas the same functions as were normally carried on by the old foot which had degenerated within the tube it was imprisoned in. The first action after becoming fastened by the foot consists in contraction into a form which will be that of the future sac end of the dwelling (Fig. 11) and then in this shortened and swollen form the animal secretes from all its general surface, excepting the anterior face that bears the adoral zone, a material which hardens in the water and forms a complete envelope about the animal partaking of its form and thus molding a sac with end open where the anterior face of the animal projects and does not secrete. This secreted sac lies all in one plane and generally has marked bilateral symmetry, since it is attached along one face which is flattened, but in such examples as the present where standing out rather free into the water the sac (Fig. 12) is not so markedly bilateral.

After the sac is completed it is continued as the tube, but this

always forms an angle with the axis of the sac (Figs. 1–14). To produce this abrupt change of angle and to form the spiral tube the animal has the habit of modifying the anterior region to make a sort of temporary head or cylindrical plug which projects out of the sac and acts differently from the region of the animal that remains within the sac. This plug-like head sticking out of the sac like a cork in a bottle turns upward at a large angle to the main axis of the sac, and thus generally at a large angle with the surface of attachment, be it vertically above or below. This angle in the main axis of the animal is maintained during the making of the tube and the tube is made round about the head region, little by little as the head region is extended farther and farther away from the foot by the gradual elongation of the whole animal. The length of the head or secreting region is such as to produce one of the component rings of the tube and it makes first the bottom one, then the next. However, these are not commonly made as mere rings but as parts of a continuous spiral, since, in proportion as the head slowly advances the head revolves and bends laterally, or nutates, secreting successively left, ventral, right, dorsal and so on. There are then three co-ordinated actions in this making of a spiral tube: first, the slow elongation of the animal, second the contractions of its anterior end to make a mold or form about which secretion is deposited, third the revolution of the head and also what might at first be called a fourth, the localization of secretion so that it is not uniform all round about at any one moment. This latter factor is the least readily made out and involves the appreciation of the fact that the spiral is really bounded by a hollow ridge due to a duplication of the tube wall and this duplication arises from the form and revolution. That is, as one side of the head is more flat it makes the straight walls of tube but as opposite side is bulged out it makes convex ridge and as revolution brings these sides into play successively the bulged out secretion is lined inside by the flat wall. The tube is smooth within but presents a spiral hollow ridge on the outside only.

The animal here considered proceeded normally with this spiral activity till five or six rounds had been finished (Fig. 13) and then made ready to complete the dwelling by the addition

of the everted lip. The making of the lip is one of the most specialized associations of form and secretion in the whole gamut of changes that the animal can run through. As indicated in Figs. 12–13 the head that has been held for more than an hour during the secretion of the spiral tube like a short plug or cork in form and position now suddenly changes into a flat terminal disk which projects outward all round about the mouth of the tube like a mushroom cap from the body of the animal as a stalk. In this mushroom, or disk-phase, of the head the adoral zone becomes excentric on the terminal face of the disk and soon disorganizing changes of the central parts initiate the future completion of dedifferentiations that are to be followed by the differentiation of new arms or feeding organs. But first the overhanging rim of the mushroom normally secretes from its lower surface an annular continuation of the tube which lacks any spiral element and terminates the tube as a horizontal shelf, convex on top; that is, an everted rounded collar comparable to the everted lip of many a potter's jar. However, in this particular instance the collar was never completed, since at 1 o'clock, August 30, a small planarian imprisoned in the hanging drop came over the incomplete dwelling of the *Folliculina* and in one minute, thrusting its proboscis into the tube as the *Folliculina* withdrew, with a few gulps, sucked the entire *Folliculina* up into its digestive cavity.

But for this unexpected event the *Folliculina* would probably have soon completed the lip of its dwelling tube and then have differentiated the usual feeding apparatus, with the aid of which it might have accumulated energy and eventually have returned to normal size after successive alternations of form and of activity.

Comparing the alternations of phases of the normal with those in this individual hampered by restrictions, we observe that the normal was nearly attained, except in the function of secreting a house; and in periods of time closely alike in the two cases.

There is here remarkable adherence to the normal rhythm despite changed external conditions. When the feeding form could not expand and feed as normal it retrograded into the swimming mouthless phase and this after the usual time of

swimming activity though not exposed to outside environment but still within the same house in which the feeding phase had lived, settled down and differentiated the feeding apparatus again, though it skipped the usual making of a house. This feeding stage not functioning as such again reverted to the swimming phase which partly escaped from confinement but was held tethered for such a long time that the next phase, the settling and house building phase came into expression, with the result that the anterior part of the animal made such a house as is normally made by the entire animal while the posterior part of the animal underwent cytolysis.

This comparison may be put in tabular form:

The Average Folliculina.		The Imprisoned Folliculina.
To use and resolve arms.....	Many hours	About twelve hours
Only to resolve arms.....	Several hours	Two hours and more
Free-swimming phase.....	Two hours and more	Two hours and more (inside house)
To make sac.....	One half hour	
To make tube.....	Few hours	
To make lip.....	Quarter to half hour	All omitted
To make whole house.....	Four to eight hours	
To differentiate arms, etc.....	One and three quarter to four and a half hours	Six hours
Again to use and resolve arms..	Many hours	Nine hours or less
Free-swimming phase.....	Two hours and more	Four hours (partly out of house)
To make sac.....	One half hour	One hour
To make tube.....	Few hours	Two hours
To make lip.....	Quarter to half hour	Seven teen minutes (when stopped undone)

It is then evident that long journeys through the water are not necessary preliminaries to the settling down of the swimmer to secrete and to differentiate. That the use of the feeding apparatus is not necessary preliminary to the dedifferentiation of the complex form into the simple; and that the anterior part of the animal can act like a whole animal. In brief the external conditions are not, for a time at all events, the necessary determining factors in the transformations back and forth from sedentary complex to migratory simple forms, or phases. Some internal factors must be decisive in the alternation of forms.

That time is spent in one phase and again in the next phase

suggests a series of internal events that must be accomplished before each phase must give place to the next.

As is often the case in normal specimens the free swimming phases in this imprisoned animal were in the daytime and the sedentary phases in the night-time so that one might suppose the phases to be dependent upon some concomitant of day and night alternations, especially as the animal is deeply pigmented both in its granules and also throughout its plasma, so that it should be affected by light and heat; however, there were many instances where the transitions from phase to phase seemed to be quite independent of alternations of light and darkness. The free swimming forms are very responsive to light and generally positive and this favors their swarming out in the daytime. However the dedifferentiation that precedes swarming may be associated with metabolic changes that have but remote connection with diurnal changes. How far these internal factors may be thought of along the lines suggested by E. J. Lund (8) remains for future experimentation to discover.

As in bursaria so in folliculina the nuclei remain apparently unchanged during the transformations from phase to phase and the transformations are those of the organs of external relation, feeding, muscular and ciliary movements and responsiveness.

Regarding the closure of the tube as presenting problems to be solved by the folliculina, it is difficult to see how an intelligent animal could have solved them more satisfactorily with the implements at hand: and were there a complex nerve system present we might assume activities within it like those of a higher animal, such as would lead to omission of the secretion of a useless dwelling after some tactual appreciation of the existence of one formerly secreted.

Granting some internal sequences that lead to alternate forms despite usual or unusual external conditions the most difficult question is why the secretion of a dwelling was omitted when the animal was held confined within the old dwelling. The omission of this series of activities that normally takes place like a chain of reflexes, leads to the appearance of a remarkable parsimony, as if the presence of the old dwelling was a signal for the neglect to construct a new one.

In this connection it should be pointed out that in several instances it was observed that free-swimmers intruded into dwellings already occupied and nevertheless when the time for transformation arrived, these intruders, one in each tube, secreted a new house within the host's house; thus showing that the presence of a surrounding house need not necessarily inhibit the making of a house within a house. In such instances also there was no intelligent result, since the new house blocked the passage and neither host nor guest was ever able to feed nor to escape from the predicament (except in one instance when a tear in the side of the old tube enabled both animals to protrude their feeding arms).

SUMMARY.

In the protozoan *Folliculina* an individual imprisoned continued to pass from differentiated to dedifferentiated phases, though both were exposed to the same restricted conditions.

Imprisoned in the night of August 28 the feeding adult dedifferentiated into a swimming form which was active within the prison all the forenoon of August 29.

It then passed into the sedentary phase and omitting to construct the usual dwelling, being inside the old one, differentiated again into the perfect form by ten o'clock.

During that night it again dedifferentiated into the swimming form, still within the old dwelling to the bottom of which it had twice fastened itself.

At 8:40 in the morning of August 30 this swimming form had partly emerged through a rent in the dwelling.

This protruding anterior part of the animal swam violently, held tethered to the dying posterior half left within the dwelling.

At ten forty the free-swimming part settled down on the outside of the dwelling and carried out the normal series of acts in fabricating a new dwelling attached to the old one and almost completed at 12:40.

But at one P.M. the animal was destroyed and rhythmic alternation thus ended.

It is inferred that these alternations of form with differentiation and dedifferentiation are not directly dependent upon such external conditions as exposure to long stretches of water, feeding,

nor probably, upon direct concomitants of day and night successions.

The nature of the internal factors responsible for this apparent striving to complete the normal alternations of phase, and the causes underlying the omission of the usual making of a dwelling, which would in this case be redundant, remain to be found out. Were there a complex nervous system we might refer much of these activities to it.

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